DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, PORTLAND DISTRICT
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SEP 06 2016

Mr. Dennis McLerran
ATTN: Portland Harbor Comments
U.S. Environmental Protection Agency
805 SW Broadway, Suite 500
Portland, OR 97205

Dear Mr. McLerran:

On June 9, 2016, the Environmental Protection Agency (EPA) issued the Proposed Plan (Plan) for the remediation of the Portland Harbor Superfund Site for public comment through September 6, 2016. The U.S. Army Corps of Engineers Portland District (Corps) has reviewed the document and is providing comments on the Plan and supporting Feasibility Study with this letter.

The Corps appreciates and supports the EPA's mission to protect human health and the environment under the authority granted through the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Likewise, the Corps is responsible for carrying out our own critical missions including environmental stewardship through planning, designing, and implementing habitat restoration projects downstream of Portland Harbor; providing safe and reliable navigation for stakeholders that use the Congressionally authorized federal navigation channels in the Columbia and Lower Willamette Rivers; and reviewing regulatory permit applications for the maintenance and/or development of water-dependent projects in accordance with authorities granted to the Corps under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. While recognizing the EPA's requirements under CERCLA for its cleanup efforts at the Portland Harbor Superfund Site, the Corps hopes to retain some level of flexibility through the cleanup process to ensure that we can continue to execute our missions effectively and efficiently. In the spirit of continued partnership and cooperation with the EPA, the Corps is respectfully submitting the enclosed comments (Table 1) for consideration.

Of the comments made, the Corps would like to emphasize one concern regarding the contaminant thresholds contained in the Feasibility Study and Plan. The planned thresholds are significantly lower than those currently being used in the Sediment Evaluation Framework (SEF); a Framework created in part and supported by EPA. We believe that the lower thresholds are, in some cases unattainable, and would adversely impact Congressionally-authorized beneficial use programs, habitat restoration efforts, and regional sediment management.

Under these preliminary remedial goals (PRGs), in-water placement of dredge material would not be allowed from any Lower Willamette River projects. The Corps considers dredged material to be a valuable resource in many ways. For instance:

- Clean dredged material can be used to build shallow water habitat for sensitive and federally-protected species.
- Retaining suitable dredged material in the Columbia and Lower Willamette watershed (via aquatic dredge material disposal) supports off-channel habitat development through the accumulation of disposed material and maintains existing shallow water habitats.
- Maximum retention of sediment in the watershed curbs beach erosion and helps to maintain a balanced sediment budget within the system.

These are just some of the lost benefits if basically all material is required to be removed from the river system. Furthermore, the Plan's proposed thresholds would require dredged material to be re-handled upland, which would not only prevent clean sediment from entering the system downstream helping speed the remediation process it would occur at three to five times the cost of in-water placement.

As mentioned, the attachment lists other comments in detail. Thank you for the chance to comment and the Corps looks forward to continuing to work with the EPA as we jointly implement our missions in the Lower Willamette River.

Jose L. Aguilar
Colonel, U.S. Army
Commander

Enclosures

cc:
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Table 1. Corps of Engineers, Portland District comments on the proposed Plan/Feasibility study for cleaning up the Portland Harbor Superfund Site.

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GENERAL COMMENTS			
Sediment Evaluation in Pacific Northwest			
Regional Sediment Evaluation	Proposed Plan/ Feasibility Study	General comment	The Portland District uses the 2016 Sediment Evaluation Framework for the Pacific Northwest (SEF) to evaluate the suitability of dredged material for unconfined, aquatic disposal in accordance with Clean Water Act (Sec. 404) and Marine Protection, Research, and Sanctuaries Act (Sec. 103) sediment testing regulations. The Portland Sediment Evaluation Team (PSET) uses the SEF (and the sediment quality guidelines published therein) to evaluate dredging projects, dam removals, and habitat restoration projects throughout Oregon and in parts of Washington along the Columbia River. The Seattle and Walla Walla Districts use the SEF (or the sediment quality guidelines published therein) as well. The SEF was developed by the interagency Northwestern Regional Sediment Evaluation Team (RSET) for use in the Pacific Northwest (in Oregon, Washington, and Idaho). The SEF contains both marine and freshwater benthic toxicity screening levels. Each state currently has its own procedures for evaluating the risks posed by bioaccumulative chemicals of concern (BCoCs), because the rules governing BCoCs vary between states. The PSET uses the Oregon Department of Environmental Quality's (ODEQ) 2007 screening level values to evaluate these risks. The RSET working to find a regional solution to address BCoCs in sediment. It is important for EPA to note that the SEF can also be used to identify the need for cleanup, because the sampling and analytical methods prescribed in the document were developed by the EPA. The SEF has been used in tandem with EPA cleanup projects in other parts of Region 10, most notably in Seattle's Lower Duwamish Waterway cleanup. Oregon's state cleanup program has also sometimes deferred to the sediment quality guidelines published in the SEF (either in whole or in part), rather than develop site-specific cleanup thresholds.
Corps Environmental Stewardship Mission and Beneficial Use of Dredged Material			
Habitat Restoration	Proposed Plan/	General comment	The Corps' Environmental Stewardship mission has benefited thousands of acres of off-channel habitat in the Lower Columbia River floodplain and estuary. EPA's Proposed Plan

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and Support/ Maintenance of Aquatic Habitat	Feasibility Study		negatively impacts the Corps' ability to accomplish this mission. EPA's proposal to apply their preliminary remedial goals (PRGs) to projects outside the sediment management areas within identified cleanup sites eliminates unconfined, aquatic disposal of dredged material as an option. The Corps (and EPA) considers dredged material to be a valuable resource in various ways, including: • Clean dredged material can be used to build shallow water habitat for sensitive and federally-protected species • Retaining suitable dredged material in the Columbia and Lower Willamette watershed (via aquatic disposal from the Corps' federal navigation projects) supports off-channel habitat development through the accumulation of disposed material and maintains existing shallow water habitats. • Maximum retention of sediment in the watershed curbs beach erosion at the mouth of the Columbia River and helps to maintain a balanced sediment budget within the system.
Beneficial Use	Proposed Plan/ Feasibility Study	General comment	Dredged material determined to be suitable for unconfined, aquatic disposal per the 2016 SEF is a resource that could be used to meet EPA's cleanup objectives. SEF-suitable material that is placed upstream of the Superfund Site would be incorporated into the suspended and bed loads of the Lower Willamette River (LWR) and transported into and through the harbor. The concentrations of contaminants in SEF-suitable dredged material and in the ambient suspended and bed load sediment are similar. The deposition of SEF-suitable dredged material within Portland Harbor would help to achieve monitored natural recovery because the concentrations in SEF-suitable dredged materials are significantly lower than those encountered in contaminated sites in the Superfund Site and are protective of benthic organisms.
Support/ Maintenance of Aquatic Habitat	Proposed Plan/ Feasibility Study	General comment	Dredged material determined suitable for unconfined, aquatic disposal per the 2016 SEF is also a valuable resource. Suitable material that is placed upstream of the Superfund Site would be incorporated into the suspended and bed loads of the LWR and transported through Portland Harbor and into the Lower Columbia River. Maximum retention of sediment in the Lower Columbia River is highly desired to curb beach erosion that is an ever present threat at the mouth of the Columbia River. The sediment quality of the suspended bedload in and immediately upstream of the LWR should be considered for unconfined, aquatic disposal. The sediments determined to be suitable for aquatic disposal per the 2016 SEF are similar in quality to the sediments that are

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			currently being deposited in the Superfund Site. As part of the study, the Lower Willamette Group collected sediment trap data, which can be used to support the monitored natural recovery strategy and help EPA to justify aquatic disposal of dredged material from non-cleanup projects. It has also been the Corps' experience that the National Marine Fisheries Service (NMFS) prefers aquatic disposal of SEF-suitable dredged materials (as opposed to upland disposal, Confined Disposal Facility (CDF), etc.), because these sediments build and/or sustain shallow water habitats in and downstream of Portland Harbor. By extension, loss of sediment from the watershed negatively affects aquatic species that require sediments for habitat, including federally-listed salmonids. The adverse effects of further limiting available suitable sediments to listed salmon species and their designated critical habitat must be considered pursuant to the Endangered Species Act.
Corps Navigation and Regulatory Permitting Missions			
Sediment Quality	Proposed Plan/ Feasibility Study	General comment	The Portland District uses the SEF to evaluate the suitability of dredged material for unconfined, aquatic disposal in accordance with Clean Water Act (Sec. 404) and Marine Protection, Research and Sanctuaries Act (Sec. 103) sediment testing regulations. It is worth noting that unconfined, aquatic disposal of dredged material is the most common mode of disposal in Oregon. It is also the most economical disposal method since upland/landfill placement is 3 to 5 times more costly. In coordination with EPA, the interagency PSET has used the SEF (and the sediment quality guidelines published therein) to evaluate maintenance dredging actions in the LWR federal navigation channel (FNC) and for dredging projects adjacent to the FNC, permitted by the Regulatory Branch. Specifically, SEF-suitable material from the City of Portland's Willamette Park Boat Ramp and the Port of Portland Terminals 2, 4, and 5 was allowed to be disposed in the Columbia River flow lane off the western tip of Hayden Island in approximately 80 feet of water. The Corps' ability to permit flow lane disposal of SEF-suitable material changed in July 2015. In example, the Corps assisted the U.S. Coast Guard (USCG) with sediment sampling to support their maintenance dredging permit for the USCG Cutter *Bluebell* slip located in the Swan Island Lagoon. Aquatic disposal of the SEF-suitable dredged material was proposed by USCG and initially supported by EPA. However, this decision was reversed after the Corps

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			Regulatory Branch issued the public notice for the project. EPA then evaluated USCG's project sediments using the PRGs published in the July 2015 Draft Final Feasibility Study, and since then, EPA Cleanup has applied these shifting sediment thresholds to projects throughout the LWR. As a recent example, the McCormick Pier Condominium Association ([MCPA] LWR, RM 11.7W) characterized approximately 850 cubic yards (cy) of dredged material to support their maintenance dredging permit. The Corps and EPA reviewed MPCA's 24 August 2016 Sediment Characterization Report (SCR) on 31 August 2016. The PSET's preliminary determination for this project is that both the dredge prism material and post-dredge surface sediment are suitable per the 2016 SEF. However, EPA's preliminary determination is that these materials are not suitable because the bulk sediment concentrations exceed the PRGs for arsenic, mercury, carcinogenic polycyclic aromatic hydrocarbons (cPAHs, benzo-a-pyrene [BaP] equivalent), hexachloro-benzene, dieldrin, total DDX, total chlordanes, and total polychlorinated biphenyls (PCB Aroclors).
Sediment Quality	Proposed Plan/ Feasibility Study	General comment	In February 2016, the Corps selected 17 projects in the Willamette River watershed in which the PSET determined the dredge material was suitable for unconfined, aquatic disposal per the SEF guidance (projects were evaluated by the PSET between 2009 and 2015) for comparison with the PRGs. The Corps provided EPA with a retrospective analysis of sediment chemical data from these 17 projects (Attachment A). Dredged material from all 17 projects exceeded at least one of EPA's PRGs. The Corps' analysis indicates that EPA's PRGs are unattainable for most, if not all, projects in the LWR located outside of proposed sediment management areas. Specifically, the Corps finds the following PRGs to be excessively low: arsenic, mercury, dieldrin, hexachlorobenzene, cPAHs (BaP equivalent), DDx, PCBs (total Aroclors), and all dioxins/furans congeners.
Sediment Quality	Feasibility Study	Figures 1.2-6a/b to 1.2-18a/b	Figures 1.2-6a/b to 1.2-18a/b of the Feasibility Study provide clear, visual evidence that EPA's proposed PRGs are unattainable. Most of these figures show chemical concentrations above the proposed PRGs distributed throughout the non-cleanup portions of the Harbor (Attachment B). With low-level concentrations of contaminants so broadly distributed throughout the Harbor, and outside of proposed sediment management areas, please explain how the proposed PRGs will be achieved in a reasonable timeframe.

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			E.g., EPA's proposed PRG for total PCBs is 9.0 ppb. Out of approximately 1,200 detected results, approximately 600 surface sediment samples have total PCBs concentrations ranging from >9 to 50 ppb; many of which are outside of proposed sediment management areas. Another 400 samples show total PCBs concentrations ranging from >50 to >1,000 ppb. Only 200 samples had total PCBs concentrations at 9 ppb or less. Therefore, how does EPA expect to achieve a remedial goal of 9 ppb or less, when 83% of the surface sediment distributed throughout the Harbor contains concentrations greater than 9 ppb total PCBs, and only 50% of the surface sediment in non-cleanup areas ranges from 9 to <50 ppb? EPA's proposed PRG for arsenic is 3 ppm. Approximately 1,200 surface sediment samples have arsenic concentrations ranging from >3 to 10 ppm and less than 100 samples are above 10 ppm; many of these points are outside of proposed sediment management areas. Approximately 450 points are <3 ppm. How does EPA expect to achieve a remedial goal of 3 ppm or less, when most of the sediment outside of proposed sediment management areas ranges from 3 to 10 ppm?
Sediment Quality	Feasibility Study	Figures 1.2-6a/b to 1.2-18a/b	EPA has developed proposed PRGs for most of the compounds depicted in these figures. The break between the lowest concentration group and the next-lowest concentration group needs to be the same as the PRG. For example, in Figures 1.2-11a/b (total chlordanes), the lowest concentration grouping ranges from 0 ppb (non-detect) to 1.5 ppb, and the next grouping ranges from >1.5 to 5.0 ppb. However, the proposed PRG for total chlordanes is 0.5 ppb. Please modify these figures (and the inset bar graph) with the break between the lowest concentration group and the next-lowest concentration group set at 0.5 ppb.
Sediment Quality	Feasibility Study	Figures 1.2-7a/b	Since EPA has developed draft PRGs for multiple PCDD/F congeners (2,3,7,8-TCDD; 2,3,7,8-TCDF; 1,2,3,7,8-PeCDD; 2,3,4,7,8-PeCDF; and 1,2,3,4,7,8-HxCDF), please prepare separate figures showing the surface/subsurface concentrations of each congener.
Sediment Quality	Feasibility Study	Figures 1.2-9a/b	Since EPA has developed a draft PRG of 12 ppb for total cPAHs (BaP equivalent), please prepare a separate figure showing the surface/subsurface concentrations of total cPAHs with the first break at 12 ppb. This exercise will also illustrate the unattainability of this proposed PRG.
Sediment Quality	Proposed Plan/ Feasibility Study	General comment	EPA's handling of non-cleanup areas within Superfund study areas is inconsistent within Region 10. In coordination with EPA Cleanup, the interagency Washington Dredged Material Management Program (DMMP) has been allowed to evaluate routine maintenance dredging projects in the Lower Duwamish Waterway (LDW) using the guidelines published in the 2016 SEF. It is our understanding that EPA required that contaminant concentrations in the

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			dredged material (and post-dredge surface material) be less than the LDW remedial action levels (RALs). The SEF screening marine screening levels are well below the LDW RALs, and so EPA allowed the DMMP to evaluate maintenance dredging projects within the LDW. Material from the LDW was permitted to go to the disposal sites managed by the DMMP. The interagency PSET facilitates the review of dredging projects in the Portland Harbor and throughout Oregon. However, contrary to the LDW cleanup, the PSET has been removed from regulatory decision-making regarding the disposition of dredged material outside of EPA-proposed sediment management areas. Instead of allowing regionally accepted freshwater screening levels to be applied outside of sediment management areas (e.g., in the LWR FNC), the Proposed Plan requires dredged material to meet PRGs that are significantly lower that the SEF freshwater guidelines and several orders of magnitude lower than the proposed RALs. As it was in the LDW, all of the SEF freshwater screening levels (SLs) are lower than the preferred alternative's RALs. In coordination with EPA, the PSET should be allowed to use the SEF to evaluate dredged material suitability in the Portland Harbor outside of proposed sediment management areas.
Sediment Quality	Proposed Plan/ Feasibility Study	General comment	As demonstrated in the Attachment A, 100% of the 17 past projects evaluated by the PSET, and determined to be suitable under the SEF, fails at least one of EPA's proposed PRGs. Before finalizing these thresholds, EPA needs to evaluate the impact of applying the PRGs on these projects outside of proposed sediment management areas within the Harbor, and clearly justify the efficacy of their use relative to existing, regionally accepted sediment chemical thresholds published in the SEF. The disparities between EPA's PRGs and the 2016 SEF freshwater screening levels has potentially far-reaching consequences, not only in the LWR, but for projects along the Lower Columbia River. The Corps and the RSET agencies are concerned that application of the Portland Harbor PRGs will migrate outside of Portland Harbor to projects on the Lower Columbia River. Projects along the Lower Columbia River are evaluated by the interagency local review teams in Oregon (the PSET) and Washington (the DMMP). Both teams use the screening levels published in the SEF for the Pacific Northwest to determine dredged material suitability for unconfined, aquatic placement. The Corps is concerned about these disparities, given that EPA is signatory to the SEF and jointly led (with the Corps' Northwestern Division) the RSET to update the SEF in July 2016. By mandating the use of these PRGs in the

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			Portland Harbor, the Corps is concerned that their application could have the unintended consequence of extending to projects up and downstream of the Portland Harbor. The Corps requests that the PSET continue to be allowed to make dredged material suitability determinations for projects outside of proposed sediment management areas (i.e., areas with MNR as the proposed remedy). The SEF freshwater benthic toxicity screening levels are protective of benthic communities, and the PSET uses the screening levels and other ecological overlays (e.g., ODEQ's screening level values for bioaccumulative compounds in sediment) to make sound regulatory decisions regarding the disposition of dredged material. Material that is determined suitable for aquatic placement by the PSET is typically placed in deep water, flow lane placement areas. Through their project evaluations, the PSET would continue to coordinate and collaborate with EPA to identify the vertical and areal extent of Principal Threat Waste (PTW) in the dredge areas of the LWR FNC and adjacent maritime industries.
Sediment Quality	Proposed Plan/ Feasibility Study	General comment	EPA's PRGs include many chemicals of concern that are not included as RALs. For example, there are no RALs for arsenic, mercury, dieldrin, hexachlorobenzene, or cPAHs. Please explain why there are excessively low PRGs for these chemicals in addition to the chemicals with established RALs.
Project Cost Impacts	Proposed Plan/ Feasibility Study	General comment	EPA must consider and disclose the peripheral impact of applying the PRGs to both cleanup and non-cleanup areas in the Superfund Site. The Corps cannot find any analysis or consideration in the Proposed Plan or Feasibility Study regarding the impact that EPA's PRGs will have to dredging proponents (including the Corps) outside of proposed sediment management areas (i.e., areas with MNR as the proposed remedy). As a consequence of applying the proposed PRGs, dredged material that is determined suitable under the SEF would not be approved for unconfined, aquatic disposal by EPA Cleanup. Further, it is not apparent whether EPA considered or evaluated the environmental impacts and costs that would be incurred by applying the PRGs outside of sediment management areas within the Portland Harbor. Under EPA's proposal, *all* dredged material would require confined disposal, not just the material in designated sediment management areas. As such, EPA has underestimated the disposal volumes under their preferred alternative. Applying the PRGs is part of EPA's proposed action, and the total maintenance volume of material outside the sediment management area that does not meet the PRGs (i.e., the remaining maintenance volume from all non-cleanup projects and the LWR FNC) needs to be included

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			in EPA's estimates. The Corps provides the following estimates (as of August 2016) ***if*** LWR FNC dredging were to occur: • Upland disposal of dredge material is 3 to 5 times the cost of in-water disposal • To dredge the LWR FNC to its currently maintained depth of -40 ft. Columbia River Datum ([CRD] plus 2 ft. advanced maintenance), the Corps would need to dredge approximately 4.4 Mcy to maintain this minimum operational depth from the confluence up to the Broadway Bridge. • The Corps estimates the volume to construct the LWR FNC to the Congressionally-authorized depth of -43 ft. CRD (plus 2 ft. advanced maintenance) would be approximately 6.7 Mcy (this includes the overlying 4.4 Mcy maintenance volume). • Of the 4.4 Mcy maintenance volume, the Corps estimates that approximately 50% (approximately 2.2 Mcy) would likely be determined suitable for aquatic disposal per the SEF. • Using the SEF and allowing for aquatic disposal of approximately 50% of material dredged, channel maintenance would cost taxpayers approximately $170M (assuming $15/cy for suitable material and $60 for unsuitable material). • If EPA's PRGs are applied so all material must be placed upland, the cost of channel maintenance would increase by approximately $100M to $270M (4.4 Mcy at $60/cy). • These figures represent a snapshot in time, and do not account for the Corps future maintenance needs in the LWR FNC (with either the -40 or -43 ft. channel). It should be noted that these costs are included as estimates for potential future dredging in the FNC. Due to the increase in costs of disposal, any Corps dredging projects will require additional study to determine the feasibility of the project.
Sediment Quality	Proposed Plan/ Feasibility Study	Global	The Corps is concerned that EPA's geographic scope of the application of the PRGs extends to Willamette Falls (RM 26.8). Evaluation of projects outside of the proposed sediment management areas in Portland Harbor should remain the province of the PSET. The PRGs should not apply to these projects beyond the limits of the Superfund Site (e.g., if a small moorage above RM 15 meets the SEF guidelines for unconfined, aquatic disposal, then the proponent should be able to barge the material to the Columbia River). If concentrations in the dredge prism are similar to concentrations found in the ambient bed load of the LWR, then flow lane disposal in the LWR should be allowed. The geographic scope of the Plan and Feasibility Study needs to be clearly defined in these documents.
COMMENTS SPECIFIC TO THE PLAN AND FEASIBILITY STUDY			

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Sediment Quality	Proposed Plan	Page 3	EPA has identified PCBs, dioxins/furans, PAHs, and DDx as the Contaminants of Concern (CoCs) that "pose the greatest potential risk to human health and the environment…". This implies that other CoCs may pose some risk, but they do not pose the greatest risk. Please explain the rationale as to why there are PRGs for the other 64 CoCs (mercury, hexachloro-benzene, aldrin, dieldrin, etc.) that already have regional thresholds that are used in the Pacific Northwest and have no established remedial action levels (RALs) in any of the alternatives.
Channel Dimensions	Proposed Plan	Page 4	The Corps is authorized to conduct maintenance dredging and deepening of the LWR federal navigation from -40 ft. CRD to -43 ft. CRD with 2 feet of advanced maintenance.
Project Setting	Proposed Plan	Page 11 Site Characteristics	The Willamette Falls are located at river mile 26.8, not 28.4, and the Willamette River is tidally influenced to RM 26.8. The average tidal range at the Falls is approximately 2 ft.
Channel Dimensions and Vertical Datum	Proposed Plan	Page 11 and 12, River Regions	The navigation channel depths do not include the advanced maintenance depth, which is 2 ft. below the maintenance/authorized depth (e.g., the Corps currently maintains the LWR navigation channel to -40 ft. CRD plus 2 ft. of advanced maintenance (to -42 ft. CRD)). Columbia River Datum (CRD) is the federally-established, local vertical datum for the LWR. The water depths should be consistently expressed in "ft. CRD". The navigation channel is currently authorized to be deepened to -43 ft. CRD plus 2 ft. advanced maintenance but is currently maintained to -40 ft. CRD plus 2 ft. advanced maintenance. The depths for the intermediate and shallow regions also need to be expressed in "ft. CRD", not "ft. below mean lower low water".
Document Clarity	Proposed Plan	Page 12, 13, and 14, Nature and Extent of Contamination	Tables 1-5 are missing from the document text. For clarity, these tables should be incorporated at point of discussion in the text similar to the other tables.
Navigation	Proposed Plan	Page 12, River Regions	With the exception of the Post Office Bar dredging in 2010 (RM 2.1 to 2.4), maintenance of the LWR federal channel has been deferred since Portland Harbor was added to the National Priorities List in December of 2000. The Corps is considering characterizing sediment and conducting maintenance dredging of the Albina Turning Basin (RM 10) in the near term, but the uncertainty of the Portland Harbor cleanup has delayed this critical work. Some, but not all, units of sediment in the LWR federal channel would likely be determined suitable for unconfined, aquatic disposal under the 2016 SEF.

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			However, since the Proposed Plan relies on applying excessively low PRGs to the entire harbor, including locations outside of proposed sediment management areas, unconfined, aquatic disposal of dredged material would no longer be an option for the Corps. Upland disposal of dredged material is 3 to 5 times more costly than aquatic placement, and the number of sites available for upland placement in or near the harbor is extremely limited. As stated above, EPA needs to evaluate all impacts that would result from application of the PRGs.
Sediment Quality	Proposed Plan	Page 14, PTW Figure 7	EPA's Plan needs to be flexible enough to adapt as new data become available. Figure 7 appears to be inaccurate based on the definitions provided on page 14. On page 14 of the Plan, Highly Toxic PTW areas are delineated based on "contaminated surface sediment in areas with concentrations that exceed a 1×10^{-3} risk based on consumption of fish...." Surface concentrations of PCBs and other PTW contaminants at the Post Office Bar shoal and Terminal 5 (RM 1.9-2.4) are well below the "Highly Toxic PTW" thresholds. Similarly, based on Corps sampling in 2013 and 2014, sediment at the U.S. Coast Guard's Marine Safety Unit at Swan Island does not exceed the Highly Toxic PTW thresholds.
Sediment Quality – Conceptual Site Model	Proposed Plan	BERA/BHHRA Page 16	Reasonable Maximum Exposure: EPA's conceptual site models (CSMs) drive their contaminant exposure assessment. Potential exposure of the various receptors (ecological and human) to sediment from dredging operations (at the point of dredging and at the point of disposal) needs to be more closely examined. The Corps cannot find in the Plan or Feasibility Study where EPA has prepared or considered activity-specific CSMs. For EPA's consideration, the Corps has prepared three generic CSMs specific to dredging that accompany these comments (Attachment C). The Corps has modified the 2016 SEF conceptual site model worksheet to include all of EPA's receptors from both the ecological CSM and the Human Health Risk Assessment CSM. The provided CSMs examine contaminant pathways at the dredge area (suspended sediment, generated residuals/fallback, and undisturbed residuals [Z-layer]) and at the disposal site (suspended sediment and the disposed material). For short-term, small volume dredging operations (both shallow draft and deep draft), the Corps finds that the pathways are either incomplete, or complete but insignificant. Sediment suspended during the dredging of small volume projects is suspended a short duration, and these pathways (direct contact and dietary) are incomplete or complete but insignificant for all

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			receptors. For long-term, deep-draft dredging, the Corps does find complete pathways for some ecological receptors. In each scenario, the Corps finds all human receptor pathways for dredged materials to be either complete but insignificant (I) or incomplete (X). As such, the Corps disagrees with the assumptions in the Proposed Plan and the Feasibility Study that human receptors will come into direct contact with material that is placed in the LWR or Lower Columbia River flow lanes. Therefore, the human health RAOs should not be used to evaluate non-cleanup maintenance dredging projects.
Sediment Quality	Proposed Plan	BERA/BHHRA Page 16-24	The conceptual site model regarding maintenance of deep draft marine facilities, the LWR FNC, and subsequent exposure scenarios is inaccurate. Regarding the aquatic disposal of dredged material, EPA's conceptual site model (which dictates which RAOs are applied to a dredging project) assumes that the most sensitive human receptors will be directly exposed to a unit of dredged material placed in the flow lane. For example, if 5,000 cy of sediment are dredged from a project in the LWR, EPA's conceptual site model assumes that same 5,000 cy of material will end up on the banks downstream of the point of disposal; it assumes a 1:1 ratio of material disposed to human exposure. However, suitable material that is placed in the flow lane would be incorporated into the waterway's suspended and bed loads. The Corps estimates that approximately 1.0 Mcy of sediment is transported through the LWR to the Columbia River annually, and the quality of this sediment is similar in quality to surface sediment concentrations throughout a large portion of the LWR (Attachment D). It is true that a small fraction of the material dredged from the LWR and disposed in the LWR or lower Columbia River flow lanes may end up on the banks of the receiving waterways. However, the accumulation (and contribution) of disposed dredged material at any given point downstream of the point of disposal would be *de minimis* and no net change would be observed.
Sediment Quality	Proposed Plan	BERA/BHHRA Page 16-24	When dredged sediments are placed in water, larger grain sizes (sands and larger) quickly settle (like placing a sand cover) in low velocity waters. Finer particles (silts, clays) stay suspended in the active water column, flow lanes, and thalweg, and travel downstream with the ambient bedload of fine sediments. The contribution of fine material from the discharge of dredged material to ambient bed load of the Willamette River and downstream waters (Columbia) is very low (<1%). The likelihood of large scale deposition of fine-grained dredged materials onto the banks of the LWR is very low. As such, the risk to receptors along the

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			banks and beds downstream of the point of discharge is also very low. Based on EPA's characterization of risk posed from upland sources of contamination on the banks of the LWR, any deposition of SEF-suitable material would improve overall sediment quality (i.e., reduce concentrations of contaminants of concern) and aid in natural recovery of the LWR reaches. However, the proposed application of the PRGs will eliminate this clean sediment source.
Sediment Quality	Proposed Plan	Evaluation of Alternatives - Protection of Human Health and the Environment Page 49	Based on the activity-specific CSMs the Corps prepared for three maintenance dredging-flow lane disposal scenarios, the human health endpoints should not be applied to dredging projects. The contaminant pathways to human receptors from maintenance dredging and disposal are incomplete or insignificant, and so human health-based PRGs should definitely not be applied to maintenance dredging projects proposed outside of the proposed sediment management areas in which the dredged material has been determined to be suitable per the 2016 SEF.
Sediment Transport	Feasibility Study	Section 1.2.3.2	The term "bedded sediments" is used frequently, but it is not defined in the document. Suggest defining it as layer thickness, grain-size distribution, cohesive, non-cohesive, or a mix.
Sediment Transport	Feasibility Study	Section 1.2.3.5	Modify the first paragraph to read: "Contamination in river banks was not evaluated in the remedial investigation. Therefore, identification of contaminated banks is being managed by DEQ under an MOU with EPA. The following provides a discussion of the known contaminated banks that will be evaluated to be addressed under this response. Additional information on these sites is available from DEQ's ECSI database and in the FS database."
Sediment Transport	Feasibility Study	Section 1.2.4	The header reads: "Contaminant Fate and Transport." However, there is no discussion of "Transport" in the section.
Sediment Transport	Feasibility Study	Section 1.2.4 paragraph 4, second to last sentence	The causes of disturbances of bedded sediments should be listed e.g., dredging ship induced waves and vortices, prop wash, high flow velocities, eddy formations, etc.
Sediment Transport	Feasibility Study	Section 1.3 bullet list	Add a last bullet that says: "ODEQ's ECSI data for contaminated river banks."
Sediment Transport	Feasibility Study	Section 2.4.3.1 Second sentence	Resuspension and dispersion of dredged material are a function of many factors, including dredge type and size. However, the level of resuspension is usually reported in turbidity units and/or suspended sediment field characteristics such as sediment concentration as a function of water depth and plume length.

Discipline/ Area of Interest	Document	Document Location	Comment
Sediment Transport	Feasibility Study	Section 3.3.2.2.1 4th paragraph, last sentence	This assumption may not be sufficiently conservative. At a minimum, the sediment transport potential over a flow range should be evaluated.
Sediment Transport	Feasibility Study	4.1.2	It appears the results of EPA's sediment transport modeling are of little to no predictive value. There are coupled hydrodynamic/sediment transport models that have been used to estimate deposition and scour patterns in tidal and/or complex streams. Sediment transport modeling should be revisited.
Comments about the U.S. Moorings			
U.S. Moorings	Proposed Plan	Various figures throughout	Figure 4 and others (e.g., Figure 19a for Alternative I) show the portion of the waterway immediately riverward of the old dock at the U.S. Moorings (immediately upriver of RM 6) as being within the NAV-FMD region or otherwise addressed by dredging due to the area being in a NAV-FMD region. Appendix C of the Final Feasibility Study indicates that identification of NAV-FMD areas was, in part, based on a site use survey from November 2008. However, this dock is being removed and future site use does not warrant designation of this area for navigation or future maintenance dredging. Thus, this area north of the old dock should not be classified as being within the NAV-FMD region. Furthermore, the area requiring to be capped may change with the absence of a structure that constrains remedial construction. The document should state how the proposed alternative will deal with the changed configuration of structures that would occur.
U.S. Moorings	Proposed Plan	General document	Given that capping is recommended over large portions of the in-water U.S. Moorings and NW Natural/Gasco sites and that groundwater discharges to the Willamette River in this area, it is paramount that groundwater control actions at NW Natural/Gasco be taken prior to implementation of capping. Otherwise, uncontrolled groundwater discharge may cause faster than expected contaminant breakthrough through the caps. The document should outline the timeframe for implementing upland groundwater control actions at NW Natural/Gasco.
U.S. Moorings	Proposed Plan	Alternatives discussion	There are some instances in all alternatives where capping is assigned immediately adjacent to the navigation channel. In the event that dredging of the channel occurs in the future, the stability of a cap could be undermined. The document should state how the EPA would implement capping in this situation to prevent future slope failure if the navigation channel is dredged. The Plan should also discuss how this would impact the implementability and estimated costs of the alternatives.
U.S. Moorings	Proposed Plan	Figures 3.2-5 in the FS and	The areas of PTW – Not Reliably Contained presented in the Final Feasibility Study and the Proposed Plan are not consistent. See Figure 3.2-5 in the Feasibility Study and Figure 7 in the

Discipline/ Area of Interest	Document	Document Location	Comment
		Figure 7 in the Plan	Proposed Plan. It is unclear why these areas are different. This comment was previously made in the Sediment Quality section, but is now focusing on the area near the U.S. Moorings facility. The PTW – Not Reliably Contained area is defined, both in the Feasibility Study and the Proposed Plan, by areas with sediment concentrations greater than or equal to 320 µg/kg chlorobenzene and 140,000 µg/kg naphthalene. However, the U.S. Moorings Remedial Investigation shows sediment concentrations of naphthalene below these thresholds (and chlorobenzene was not detected). Therefore, it is difficult to understand why Figure 7 in the PP shows PTW – Not Reliably Contained occurring near the old dock at U.S. Moorings.
Overall	Proposed Plan	RAL Discussion	It is not clear what technology performance assumptions were used in estimating the residual contaminant concentrations and risks remaining immediately following construction and with time.
	Feasibility Study	Section 3.4.9	The document should mention that an on-site CDF would need to be constructed for Alternatives E-I.
Sequence of Action	Feasibility Study/ Proposed Plan	Global	The document does not discuss what actions would occur first. This is especially important for dealing with groundwater plumes. Cleanup of contaminated groundwater is being addressed and managed by DEQ under the MOU with EPA. However, in-water actions may need to be considered under this response to address residual impacts from groundwater plumes.

Attachment A

Summary of Portland Harbor Prelimilary Remedial Goals by Media
Portland Harbor Superfund Site

KEY

PRG≤ SEF SL

PRG< SEF SL, but EPA's threshold will not affect most projects

PRG < SEF SL or there is not an SEF SL for the compound

* - the PRG is at or below the LOQ for the method
^ - low-level & estimated (J-qualified) detections of this compound (or group of compounds) will always exceed the PRG in the PHSS; dredged material will always fail

Contaminant	Units	River Bank Soil/Sediment PRG	SEF FW Benthic Toxicity SL
Aldrin	µg/kg	2	--
Arsenic	mg/kg	3^	14
Benzene			
BEHP	µg/kg	135	500
Cadmium	mg/kg	0.5	2.1
Chlordanes	µg/kg	1.5	--
Chlorobenzene			
Chromium			
Copper	mg/kg	359	400
Cyanide			
DDx	µg/kg	6.1	
DDD		114	310
DDE		226	21
DDT		246	100
1,1-DCE			
cis-1,2-DCE			
Dieldrin	µg/kg	0.07*^	4.9
2,4-D			
Ethylbenzene			
Hexachlorobenzene	µg/kg	0.3*^	--
beta-hexachlorocyclohexane		7.2	
Lindane (gamma-HCH)	µg/kg	5	--
Lead	mg/kg	128	360
Manganese			
MCPP			
Mercury	mg/kg	1.1	0.66
Pentachlorophenol			
Perchlorate			
PBDEs			
PCBs	µg/kg	9*	110
Total PAHs	µg/kg	23,000	17,000

cPAHs (BaP eq)	µg/kg	12*^	--
Acenaphthene			
Acenaphthylene			
Anthracene			
Benzo(a)anthracene			
Benzo(a)pyrene			
Benzo(b)fluoranthene			
Benzo(g,h,i)perylene			
Benzo(k)fluoranthene			
Chrysene			
Dibenz(a,h)anthracene			
Fluoranthene			
Fluorene			
Indeno(1,2,3-c,d)pyrene			
2-Methylnaphthalene			
Naphthalene			
Phenanthrene			
Pyrene			
Dioxins/Furans (2,3,7,8-TCDD eq)			
1,2,3,4,7,8-HxCDF	µg/kg	0.0004^	--
1,2,3,7,8-PeCDD	µg/kg	0.0002*^	--
2,3,4,7,8-PeCDF	µg/kg	0.0003*^	--
2,3,7,8-TCDF	µg/kg	0.0004^	--
2,3,7,8-TCDD	µg/kg	0.0002*^	0.005
PCE			
Toluene			
TPH C10-C12 Aliphatic			
TBT	mg/kg	24	0.047
TCE			
2,4,5-TP			
Vanadium			
Vinyl Chloride			
Xylenes			
Zinc	mg/kg	459	3,200

Benzo(a)pyrene Toxicity Equivalency Factors for Carcinogenic PAHs (cPAHs)

CAS No.	cPAH	BaP Toxicity Equivalency Factor
50-32-8	Benzo(a)pyrene	1.00
56-55-3	Benzo(a)anthracene	0.10
205-99-2	Benzo(b)fluoranthene	0.10
207-08-9	Benzo(k)fluoranthene	0.10
218-01-9	Chrysene	0.01
53-70-3	Dibenzo(a,h)anthracene	0.10
193-39-5	Indeno(1,2,3cd)pyrene	0.10

Review and Comparison of Data from Positive Suitability Determinations on the Willamette R. (to Salem) and Clackamas R., Oregon

Project Name	RM	PSET/PRG Suitability	Arsenic	Dieldrin	Hexachloro-benzene	CONTAMINANT cPAHs (BaP eq.)	PCBs (Total Aroclors)	1,2,3,4,7,8-HxCDF	1,2,3,7,8-PeCDD	2,3,4,7,8-PeCDF	2,3,7,8-TCDF	2,3,7,8-TCDD
		PRG:	3^	0.07*^	0.3*^	12*^	9*	0.001^	0.0001*^	0.0002*^	0.0004^	0.0001*^
		Units:	mg/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
PoP, Terminal 4, Berth 401A	4.2	Suitable	FAIL (5.08)	<	<	FAIL (BaP = 68.6)	<	NA	NA	NA	NA	NA
PoP, Terminal 4, Berth 401B	4.2	Suitable	FAIL (4.89)	<	<	FAIL (BaP = 32.6)	<	NA	NA	NA	NA	NA
USCG Marine Safety Unit - Portland	7.5	Suitable/	FAIL (4.84)	FAIL (1.5)	<	FAIL (BaP = 180)	FAIL (35.3)	NA	NA	NA	NA	NA
Glacier NW	7.9	Suitable#	FAIL (4.17)	<	<	<	<	NA	NA	NA	NA	NA
PoP, Terminal 2, Berth 205A	10.0	Suitable	FAIL (4.35)	<	<	FAIL (BaP = 16.8)	<	NA	NA	NA	NA	NA
PoP, Terminal 2, Berth 205B/206	10.0	Suitable	FAIL (5.20)	<	<	FAIL (BaP = 18.3)	<	NA	NA	NA	NA	NA
Willamette Park Boat Ramp	15.8	Suitable	FAIL (3.16)	<	FAIL (2.5J)	FAIL (BaP Eq = 17.[illegible]	<	NA	NA	NA	NA	NA
Portland Rowing Club	16.8	Suitable	FAIL (8)	<	<	FAIL (BaP = 20)	<	NA	NA	NA	NA	NA
Waverly Marina	17.0	Suitable	<	<	<	FAIL (BaP = 19)	<	NA	NA	NA	NA	NA
Gabriel (Guenther) Private Boat Dock	18.5	Suitable	FAIL (3.24)	<	NA	FAIL (BaP = 17.8)	<	NA	NA	NA	NA	NA
USCG Marine Safety Unit - Portland REF	18.8	Suitable	FAIL (3.2)	<	<	<	<	NA	NA	NA	NA	NA
Rinearson Creek Restoration	24.0	Suitable	FAIL (3.1)	<	<	<	<	NA	NA	NA	NA	NA
Oregon Sportscraft Marina	25.5	Suitable	<	<	<	<	<	NA	NA	NA	NA	NA
Salem Yacht and Boat Club (Willamette R.)	88.0	Suitable	FAIL (3.82)	<	<	<	<	NA	NA	NA	NA	NA
PGE Faraday Lake (Clackamas R.)	26.5	Suitable	FAIL (4.2)	<	<	<	<	NA	NA	NA	NA	NA
PGE Promontory Park (Clackamas R.)	32.4	Suitable	FAIL (3.16)	<	<	<	<	NA	NA	NA	NA	NA
McCormick Pier Condos (screening data)	12.0	TBD	FAIL (3.1)	<	NA	<	<	NA	NA	NA	NA	NA

KEY

Suitable	Positive SDM issued by PSET, but one or more results exceed PRG
Suitable#	Negative suitability determination issued by PSET, but material would be suitable under 2015 SLs. However, one or more results exceed PRG
Suitable/	Positive SDM issued by PSET after bioassay testing, but one or more results exceed PRG
FAIL (4.84)	Detected concentration above PRG, below SEF SL
FAIL (2.5J)	Estimated concentration above PRG, below SEF SL
<	Non-detect; LOQ/LOD above PRG
<	Non-detect; LOQ/LOD below PRG
TBD	To be determined (screening data provided)
NA	Not analyzed

LOQ = limit of quantitation

LOD = limit of detection

* - the PRG is at or below the LOQ for the method

^ - low-level & estimated (J-qualified) detections of this compound (or group of compounds) will always exceed the PRG in the PHSS; dredged material will always fail

Attachment B

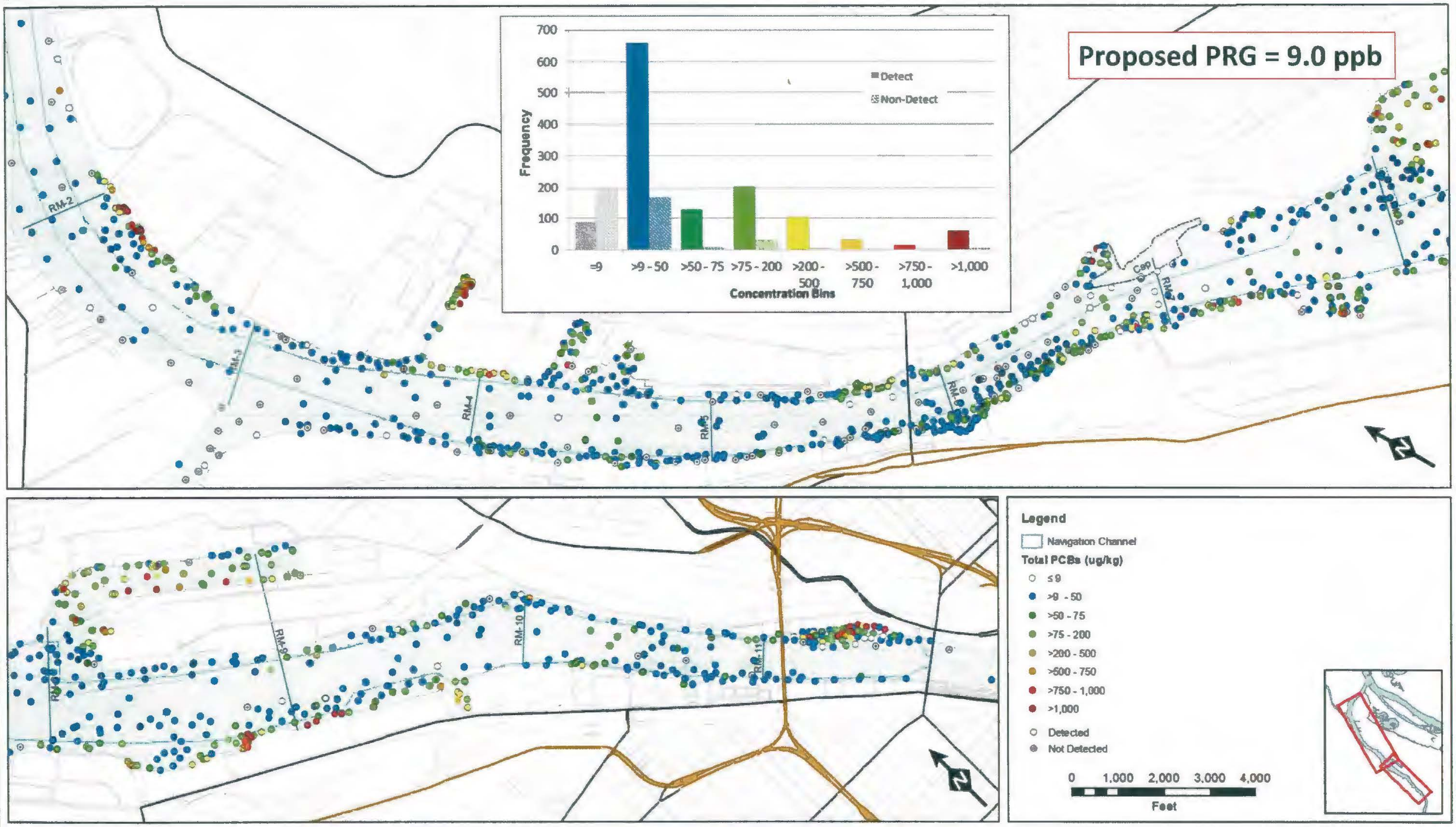


Figure 1.2-6a. Distribution of Surface Sediment Chemistry for Total PCBs

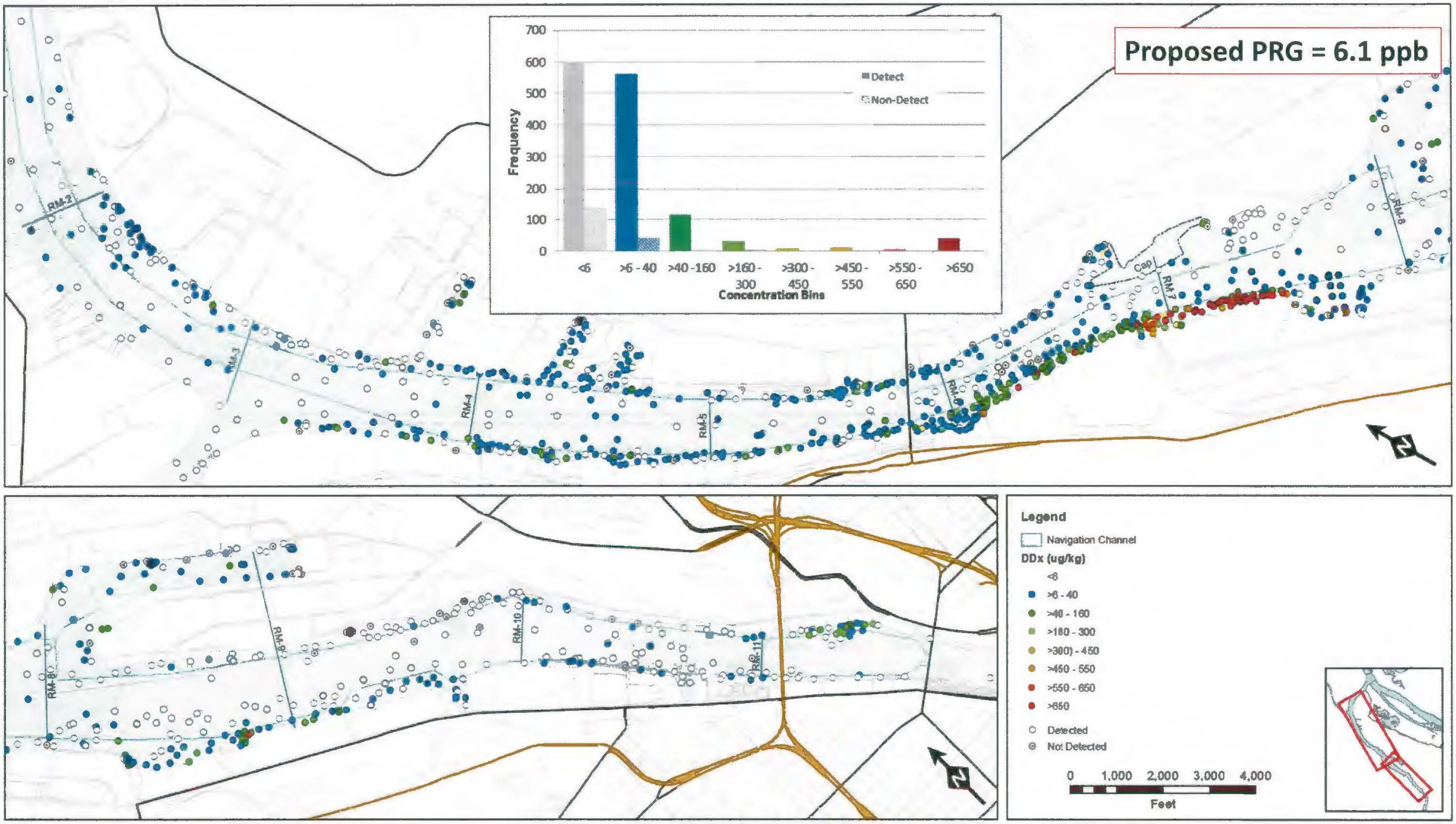


Figure 1.2-8a. Distribution of Surface Sediment Chemistry for DDx

Date: 2/22/2016

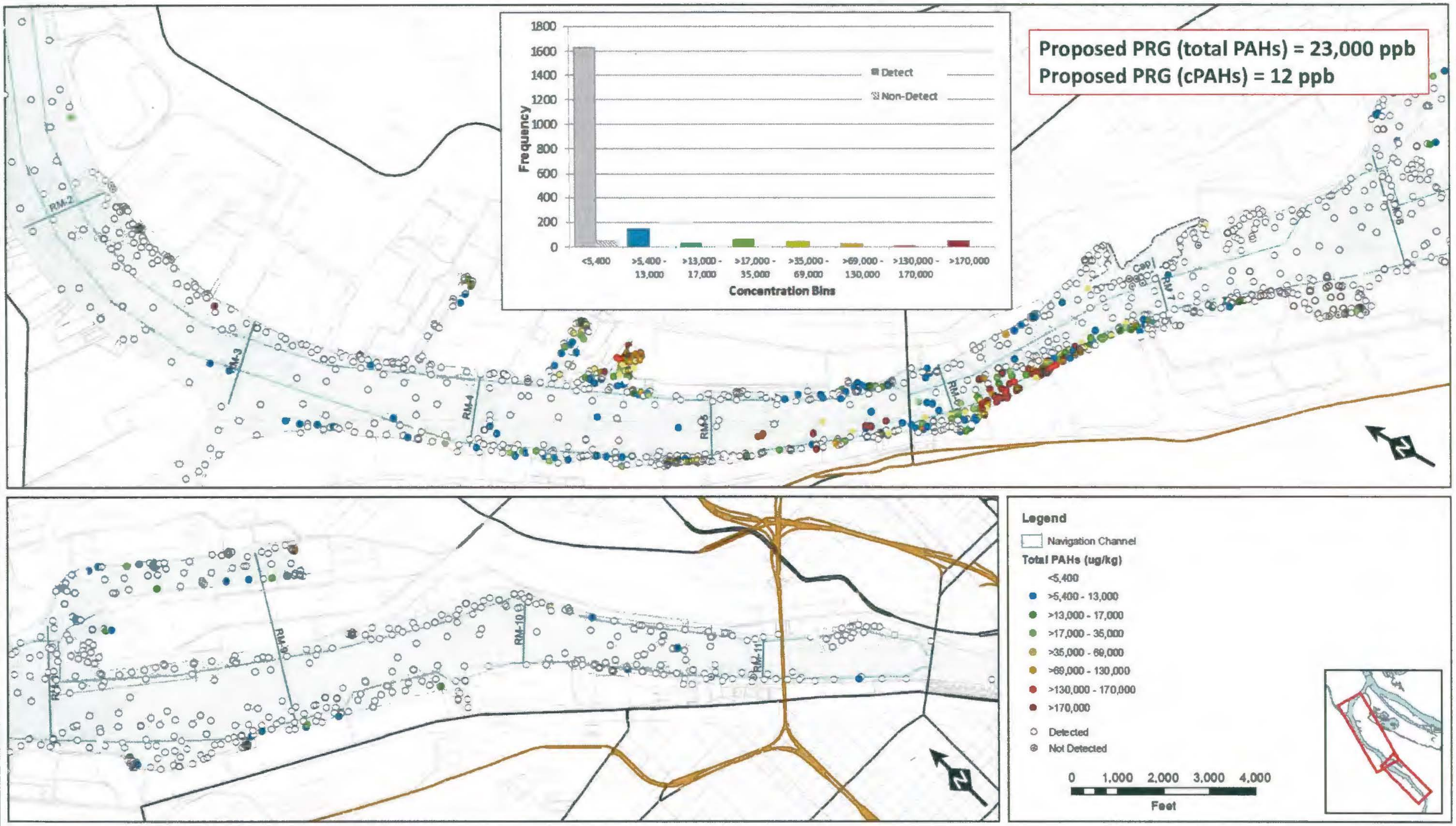


Figure 1.2-9a. Distribution of Surface Sediment Chemistry for Total PAHs

Date: 2/22/2016

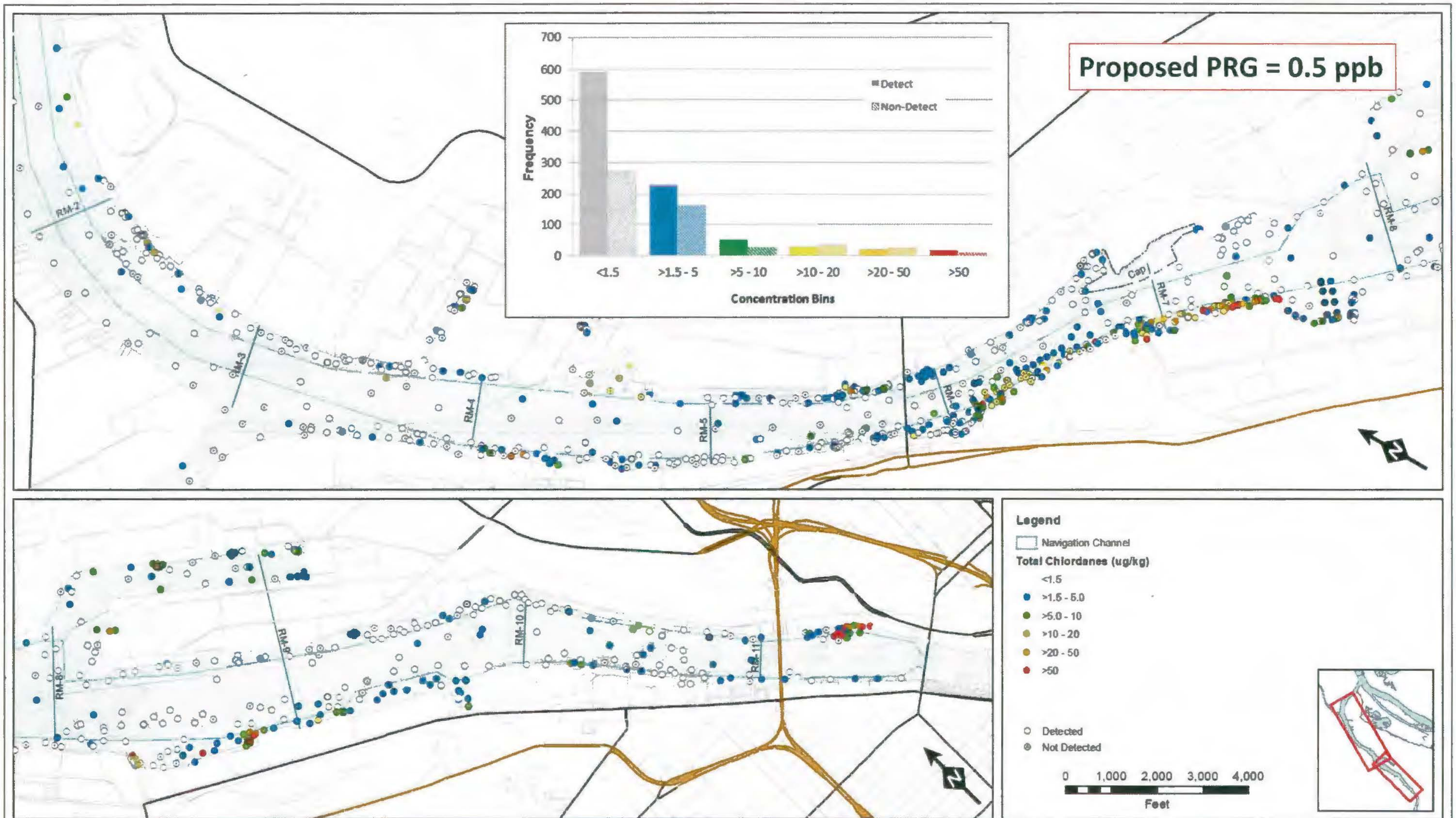


Figure 1.2-11a. Distribution of Surface Sediment Chemistry for Total Chlordanes

Date: 2/23/2016

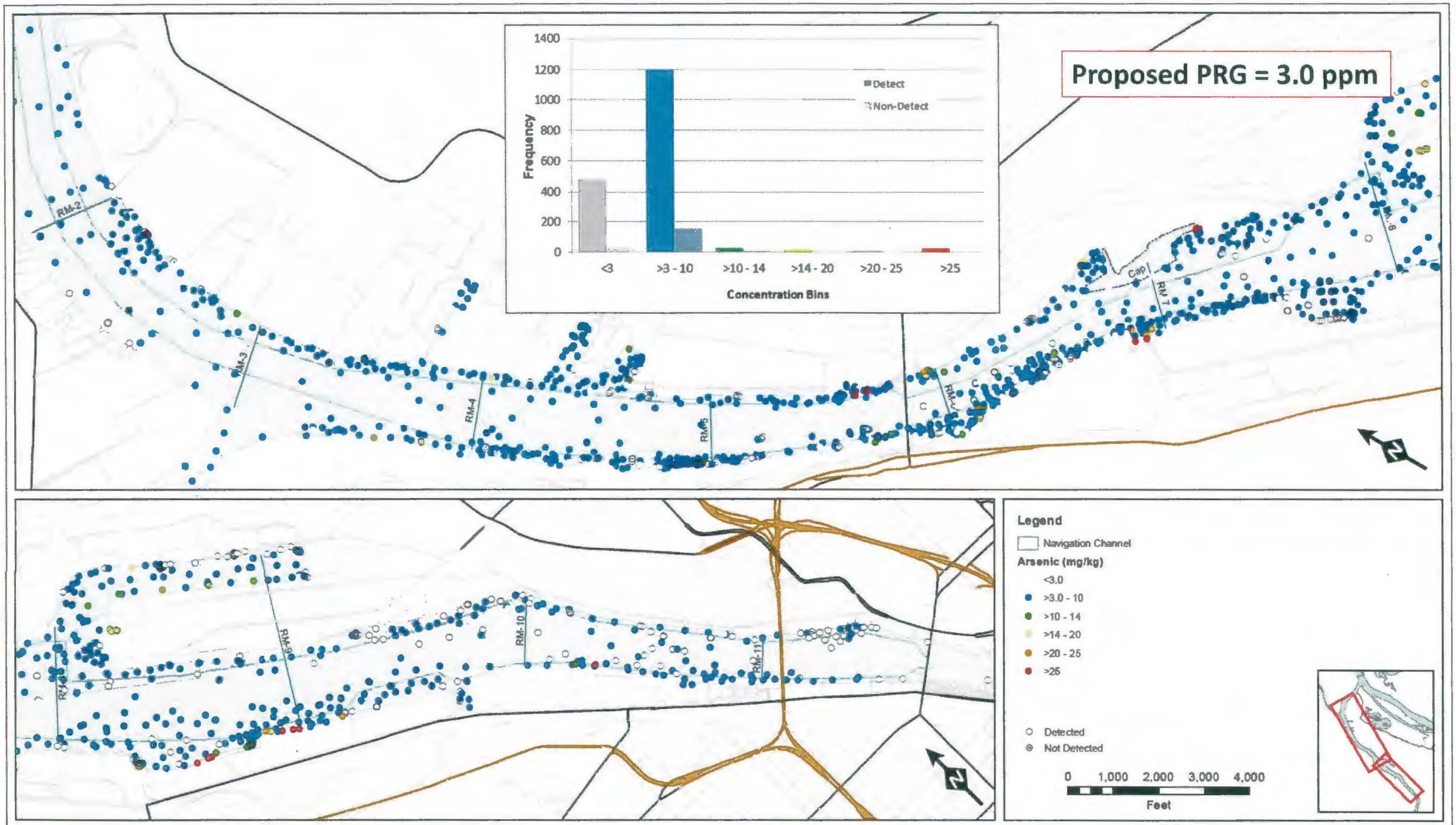


Figure 1.2-14a. Distribution of Surface Sediment Chemistry for Arsenic

Date: 2/23/2016

Attachment C

Table 2. Conceptual Site Model for Dredging and Disposal Activities – Large Volume (>50,000 cy), Long-term (>2 weeks of dredging/disposal) Dredging Project; Flow Lane Disposal.				Receptors and Habitat																	
				Invert	Fish				Birds			Herps	Mammals								
Primary Medium (Source of contaminants)	**Secondary Media** and Release Mechanism(s) (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		Benthic Inverts	Omnivorous Fish	Invertivorous	Piscivorous/	Detritivorous Fish	Omnivorous	Sediment-	Piscivorous Birds	Amphibs/Reptiles	Aquatic-Depend.	Dockside Worker	In-water Worker	Transient	Diver	Rec. Beach User	Tribal Fisher	Rec. Fisher	Dom. Water User
DREDGE AREA PATHWAYS (the routes chemicals travel between the sediment and receptors in the dredge area)																					
SEDIMENT →	**Suspended Sediment (Water Column)** Resuspension of sediment during dredging →	Direct Contact →		I	I	I	I	I	I	I	I	I	I	X	I	I	I	I	I	I	I
		Dietary →	Tertiary Media (Tissue) →	I	I	I	I	I	I	I	I	I	I	X	X	I	X	I	I	I	I
	Generated Residuals Redeposition of suspended sediments, fallback (from the excavation or debris removal), and/or slope failure and sloughing →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	I	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I
	Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	I	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I
UNCONFINED, AQUATIC DISPOSAL PATHWAYS* (the routes chemicals travel between the sediment and receptors at the disposal site)																					
SEDIMENT →	**Suspended Sediment (Water Column)** Suspension of sediment during disposal and release of interstitial water from the dredge area →	Direct Contact →		I	I	I	I	I	I	I	I	I	I	X	X	X	I	I	I	I	X
		Dietary →	Tertiary Media (Tissue) →	I	I	I	I	I	I	I	I	I	I	X	X	I	X	I	I	I	I
	Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	X	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I

Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete

* Other disposal options (confined aquatic disposal, upland confined disposal, etc.) are briefly described in Chapter 10 of the SEF. However, the evaluation of contaminant pathways and receptor exposure routes associated with confined disposal facilities is outside the scope of the SEF review (and the CSM); the unconfined, aquatic disposal pathways would be incomplete (X).

Table 3. Conceptual Site Model for Dredging and Disposal Activities – Small Volume (<50,000 cy), Short-term (<2 weeks of dredging/disposal), Deep-Draft (below -20' CRD) Dredging Project; Flow Lane Disposal.

Primary Medium (Source of contaminants)	**Secondary Media** and Release Mechanism(s) (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		Receptors and Habitat																	
				Invert	Fish				Birds			Herps	Mammals								
				Benthic Inverts	Omnivorous Fish	Invertivorous	Piscivorous/	Detritivorous	Omnivorous	Sediment-	Piscivorous Birds	Amphibs/Reptile	Aquatic-Depend.	Dockside Worker	In-water Worker	Transient	Diver	Rec. Beach User	Tribal Fisher	Rec. Fisher	Dom. Water
DREDGE AREA PATHWAYS (the routes chemicals travel between the sediment and receptors in the dredge area)																					
SEDIMENT →	**Suspended Sediment (Water Column)** Resuspension of sediment during dredging →	Direct Contact →		X	I	I	I	I	I	I	I	I	I	X	I	I	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	X	I	I	I	I	I	I	I	I	I	X	X	I	X	I	I	I	I
	Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	I	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I
	Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	I	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I
UNCONFINED, AQUATIC DISPOSAL PATHWAYS* (the routes chemicals travel between the sediment and receptors at the disposal site)																					
SEDIMENT →	**Suspended Sediment (Water Column)** Suspension of sediment during disposal and release of interstitial water from the dredge area →	Direct Contact →		X	I	I	I	I	I	I	I	I	I	X	X	X	X	X	X	X	X
		Dietary →	Tertiary Media (Tissue) →	X	I	I	I	I	I	I	I	I	I	X	X	X	X	X	X	X	X
	Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	X	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I

Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete

* Other disposal options (confined aquatic disposal, upland confined disposal, etc.) are briefly described in Chapter 10 of the SEF. However, the evaluation of contaminant pathways and receptor exposure routes associated with confined disposal facilities is outside the scope of the SEF review (and the CSM); the unconfined, aquatic disposal pathways would be incomplete (X).

Table 4. Conceptual Site Model for Dredging and Disposal Activities – Small Volume (<50,000 cy), Short-term (<2 weeks of dredging/disposal), Shallow-Draft (above -20' CRD) Dredging Project; Flow Lane Disposal.				**Receptors and Habitat**																	
				Invert	**Fish**				**Birds**			**Herps**	**Mammals**								
Primary Medium (Source of contaminants)	**Secondary Media** and Release Mechanism(s) (Processes that liberate sediment and chemicals of concern during and after dredging, providing potential avenues for receptor exposure to contaminants in the dredge area and at the disposal site)	**Exposure Route** (The point of contact or entry of a contaminant into a receptor)		Benthic Inverts	Omnivorous Fish	Invertivorous	Piscivorous/	Detritivorous Fish	Omnivorous	Sediment-	Piscivorous Birds	Amphibs/Reptiles	Aquatic-Depend.	Dockside Worker	In-water Worker	Transient	Diver	Rec. Beach User	Tribal Fisher	Rec. Fisher	Dom. Water User
DREDGE AREA PATHWAYS (the routes chemicals travel between the sediment and receptors in the dredge area)																					
SEDIMENT →	**Suspended Sediment (Water Column)** Resuspension of sediment during dredging →	Direct Contact →		X	I	I	I	I	I	I	I	I	I	X	I	I	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	X	I	I	I	I	I	I	I	I	I	X	X	I	X	I	I	I	I
	Generated Residuals Redeposition of suspended sediments, fallback (from the excavation head or debris removal), and/or slope failure and sloughing →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	I	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I
	Undisturbed Residuals Exposure of buried sediments by dredging (the Z-layer) →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	I	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I
UNCONFINED, AQUATIC DISPOSAL PATHWAYS* (the routes chemicals travel between the sediment and receptors at the disposal site)																					
SEDIMENT →	**Suspended Sediment (Water Column)** Suspension of sediment during disposal and release of interstitial water from the dredge area →	Direct Contact →		X	I	I	I	I	I	I	I	I	I	X	X	X	X	X	X	X	X
		Dietary →	Tertiary Media (Tissue) →	X	I	I	I	I	I	I	I	I	I	X	X	X	X	X	X	X	X
	Disposal Material Deposition of dredged sediment at the disposal site →	Direct Contact →		C	I	C	I	C	I	I	I	I	I	X	X	X	I	I	X	X	I
		Dietary →	Tertiary Media (Tissue) →	C	I	C	I	C	I	I	I	I	I	X	X	I	X	I	I	I	I

Pathway Completeness Abbreviations: **C** = Complete; **I** = Complete but insignificant; **X** = Incomplete

* Other disposal options (confined aquatic disposal, upland confined disposal, etc.) are briefly described in Chapter 10 of the SEF. However, the evaluation of contaminant pathways and receptor exposure routes associated with confined disposal facilities is outside the scope of the SEF review (and the CSM); the unconfined, aquatic disposal pathways would be incomplete (X).

Attachment D

Long Term Sedimentation Trends for the Lower Willamette River
(with recommendations on bank stabilization to reduce sediment discharge)
CENWP EC-HY

1.0 Sediment Transport Concepts

Sediment transport can be classified based on the mechanism by which particles move. These classifications are bed-load discharge where grains move by saltation (hopping), rolling, and sliding along or just above the bed; and suspended load -- grains that are picked up off the bed by upward components of flow and move through the water column in undulating paths.

Sediment transport can also be divided into two classes based on the source of the particles. The classes are bed material load, which are those grains found in the streambed, and wash load, which are composed of grains found only in small amounts (say 1-2 percent) in the bed. Principal sources of wash load particles are channel banks or the slope areas adjacent to the stream, or both. A major source of bed material load is from stream banks.

Wash load particles in a stream, including large deep rivers, tend to be very small (ranging from clay-sized grains to very fine sand), and hence have very low settling velocities, remain in suspension for long periods, and are transported downstream by very low channel velocities. Once wash load particles are carried down to a stream, they are kept in suspension by flow turbulence and pass through the stream with negligible deposition and interaction with the bed. Wash load is not predictable based on channel hydraulics and bed composition, and can only be predicted by the rate at which wash load sized particles enter the stream (sediment yield and delivery ratio). Although sediment yield and delivery ration are not unpredictable parameters, they are difficult to quantify; "It is difficult to compute the supply of sediment which will be brought down to the stream, because of the complexity of the variables involved." (H.A. Einstein, 1964). Conversely, the transport of bed material load (say medium sand to fine gravel) is predictable based on bed composition and the hydraulic properties of the stream.

If the supply of fine sediment in the wash load range from a basin increases, then a concomitant increase in suspended sediment discharge will be observed downstream, but grain sizes comprising the bed material should remain unchanged. However, altering the supply of sediment in the size range of the bed material will alter the composition of the bed, and likely increases the transport rates of bed material. For example, if the supply of coarse sand to a gravel bed stream is increased, then the transport rate (amount) of coarse sand-size particle usually increases as well - because more coarse sand is available to transport. In practice, the effect on bed-material transport rates resulting from an increase in the quantity of a particular grain-size class to the bed of stream is more complex then the previous statements suggest, however the basic principles expressed above is valid.

Quantitatively predicting a stream's response to change, particularly a large stream and basin system can be made if all the required data are known. Often data are insufficient for quantitative predictions and only qualitative assessments are possible. Investigators studying channel response to both natural and man-made changes in flow and sediment discharge have developed the following relations (all are not listed):

- Depth of flow is proportional to discharge, Q
- Channel width is proportional to both discharge and sediment discharge, Q_s
- Channel slope is inversely proportional to discharge and proportional to both sediment discharge and grain size, D
- Sinuosity , s, is proportional to valley slope and inversely proportional to sediment discharge

Lane (COE, 1955) and others have developed equations for qualitative predicting stream responses to change. With respect to changes in flow and sediment discharge, the equations have the following general form:

$$QS \propto Q_S D_{50} \quad \text{.....(1)}$$

Q = water discharge
S = streambed slope
Q_S = sediment discharge
D_{50} = median particle size (total load)

Equation (1) can be stated in terms of the bulleted item above; channel slope S is inversely proportional to flow Q and directly proportional to both sediment discharge and median grain size D_{50}. For example, deposition in a stream upstream of dam will result in mostly clear water being released downstream of the dam, or Q_S downstream is less than Q_S upstream. If the flow and median particle size are unchanged, then the streambed downstream will be incised. The relations represented by equation (1) are useful only as a qualitative indicator of trends in stream morphology resulting from changed conditions.

2.0 Stream Morphology

Streams erode or deposit sediment on the banks and bed over time until the channel is in quasi- or approximate-equilibrium. The terms quasi-equilibrium or approximate equilibrium are used herein because seasonal and random variations in discharge, result in true long-term equilibrium conditions never occurring.

2.1 General Principles

At the headwaters of a stream, the water is free of suspended sediment and flow velocities are high -- causing the bed to be scoured deeply. As the channel deepens, the slope (longitudinal profile) of the channel is reduced until the sediment discharge is in approximate equilibrium with erosive potential. The depth of scour is limited by geologic controls; for example, the channel is eroded to a bedrock layer. A channel that cannot deepen, however can continue to widen if excess energy is available i.e. the sediment load is not in equilibrium with transport capacity. Suspended sediment carried downstream to flatter valley reaches of a stream will deposit as cross-sectional area increases and slope decreases. The deposition of fine-grained material steepens the slope of the valley reach, which increases erosive potential of flowing water, and can cause an increase in plan form complexity. In both mountain and valley reaches of a stream, the flow area, channel plan form, and cross-sectional shape adjust in accordance with the thermodynamic principle of least work, that is, among the physical variables - channel depth and width, sinuosity, and bed slope – those most easily changed will be changed first until a quasi-equilibrium condition is achieved. Channel degradation consists of down cutting (incision), bank erosion, and head cutting. Degrading channels result in the increased production of sediment in both wash load and bed material load size classes. Wash load and bed material load sized grains are eroded from the banks, whereas sediment scoured from the streambed consists of particles in the bed material load size classes.

2.2 Bed and Bank Stabilization

Among purposes of direct channel stabilization methods are: 1) to produce a protective blanket that resists the shear force of flowing water; 2) to create bank roughness and thus reduce velocity and shear forces acting on the bank; and 3) to prevent lowering of the streambed which in turn prevents bank undercutting (Vanoni, 1975). Purpose one can be accomplished by hard armoring the banks (e.g. riprap, shotcrete, concrete), and purpose two can be accomplished through bioengineering (e.g. tree, shrubs, grasses). Both purposes one and two are achieved by combining bioengineering methods with hard armoring. Neither hard armoring the banks, nor protecting them by bioengineering methods can prevent bank undercutting, because undercutting results from scouring of the streambed adjacent to the banks. An indirect, and sometimes unintended, method for limiting channel degradation is through flow regulation; "Basin-wide control [of sediment supply] also can be accomplished by flow regulation" (Stanton and McCarlie, 1962).

3.0 Sedimentation Trends the Lower Willamette River

In a study of sediment discharge at Salem, the American Geophysical Union using data from the Corps of Engineers, the USGS, and the Soil Conservation Service estimated that 24 percent of the suspended sediment discharge came from forested land, 22 percent from agricultural land, and 54 percent from eroding channels (AGU, 1954). The sediment supply from degrading channels includes both material eroded from the banks and material scoured form the bed, and in the case of seriously degrading streams, incision (head cutting) of the streambed.

3.1 Determination of Sediment Discharge using Flow Duration-Sediment Rating Curve Method

Using methods presented in the SCS Engineering Handbook (superseded) – Chapters 3 and 6 (USDA, 1985), Anderson calculated sediment yield and delivery ratios at selected location of the Willamette River Basin, including tributary basins. Anderson and others (from the late 1940s to mid 1950s) estimated the unit sediment yield for the Willamette River at Portland to be 230-210 tons/mi^2. Using the same approach for the 1967 Willamette Basin Comprehensive Study, the Willamette Basin Task Force reported similar results at Portland-unit sediment yield as 210 tons/mi^2, and an annual total sediment discharge of 2.3 million tons (about 1.9 million tons as suspended sediment). (PNRBC, 1969).

Alternatively, sediment discharge can be directly calculated from a suspended sediment-rating curve and a flow duration curve. A sediment rating curve is a plot of mean daily flow data in (ft^3/s) as a function of total suspended-sediment discharge data (data is converted from a concentration to a mass flux and reported in tons/day). Suspended sediment and flow data collected by the USGS for the Willamette River at Portland from 1993 to 1999 are present in Table 1 (abbreviated); flow and sediment discharge data measured by the Corps for the Willamette River a Newberg from 1959-1960 are also found in Table 1.

Table 1.0: Flow and suspended sediment data for the Willamette River

Portland			Newberg		
Date	Mean daily flow, ft^3/s	Sediment discharge tons/day	Date	Mean daily flow, ft^3/s	Sediment discharge tons/day
25Jan1993	78600	8280	06Jul1959	8000	475
15Mar1993	35200	950	20Jul1959	7000	491
05Aug1993	12200	264	03Aug1959	6500	544
04Nov1993	12600	272	18Aug1959	6500	386
10May1994	13000	211	01Sep1959	9000	729
25Jul1994	7700	249	29Sep1959	17000	2341
25Oct1994	9187	183	13Oct1959	32400	4461
29Oct1994	35814	3780	27Oct1959	26000	2176
03Nov1994	59694	17700	10Nov1959	16400	797
02Dec1994	105741	35000	24Nov1959	45400	14219
24Jan1995	62944	4910	01Dec1959	21500	1800
06Mar1995	22977	358	15Dec1959	27400	4143
09Aug1995	8113	174	29Dec1959	19800	1230
26Sep1995	12402	227	28Jan1960	34300	3241
23Oct1995	18700	454	09Feb1960	92400	48150
13Nov1995	89200	20500	17Feb1960	67700	8226
27Nov1995	69700	6400	24Feb1960	30200	2120
08Jul1996	10000	81	09Mar1960	97900	23790
28Aug1996	8830	334	22Mar1960	40900	3644
22Oct1996	27800	1130	04Apr1960	84700	13493
09Jan1997	134000	18500	14Apr1960	30600	2313

28Jan1997	71000	9390	26Apr1960	39800	2686
10Dec1997	31000	753	25May1960	52700	5407
17Dec1997	43200	2330	13Jul1960	11000	683
19Dec1997	88500	18400	17Aug1960	11400	831
22Dec1997	55600	5550			
06Jan1998	45000	3160			
10Feb1998	40800	1760			
04Dec1998	160000	31100			
14Dec1998	120000	12000			
30Dec1998	240000	178000			
04Jan1999	130000	19300			
26Jan1999	140000	13200			
30Mar1999	44000	1430			
19Apr1999	36000	583			

Plot of the flow and sediment mass flux for the data are shown on Figure 1.0 below. USGS data collected from 1974-1981 are also plotted on Figure 1.0. Both axes of Figure 1.0 are logarithmic and a power function fits to the data (the sediment rating curves) are also shown on the figure.

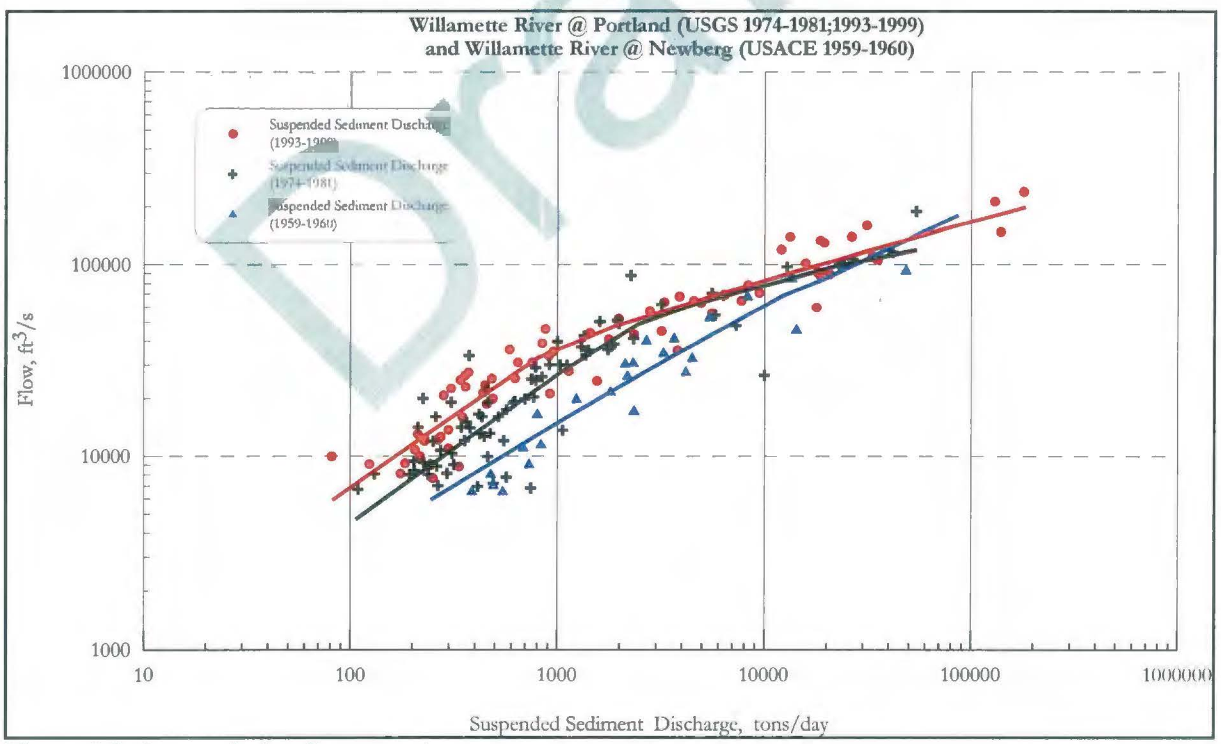


Figure 1.0: Suspended sediment rating curves

3.2 Annual flow duration curve

Although the first dam on the Willamette River began operating in 1941, the designated regulated flow period began in October 1966 (WY 1967). Flow duration values for periods of regulated and unregulated flows of the Willamette River at Salem (USGS No. 14191000) are presented in Table 1.0 below. The data is presented graphically on Figure 2.0. The bankfull discharge at Salem is approximately 90,000 ft^3/s.

Table 1.0: Willamette River @ Salem (USGS – 14191000)

Frequency, Percent	days/year	Q, ft^3/s regulated period 1967-	Q, ft^3/s Unregulated period 1909-1966
0.01	0.04	223630	325259
0.05	0.18	164777	247105
0.1	0.37	149777	232021
0.2	0.73	137518	191126
0.5	2	119000	146105
1	4	103000	125000
2	7	92836	105000
5	18	74000	74800
10	37	53800	52800
15	55	40500	41000
20	73	32780	34100
25	91	27600	29325
30	110	23870	25600
35	128	20800	22600
40	146	18400	19700
45	164	16400	17400
50	183	14900	15100
55	201	13500	12900
60	219	12200	10800
65	237	11100	8936
70	256	10100	7440
75	274	9010	6360
80	292	8102	5620
85	310	7330	4718
90	329	6801	3890
95	347	6270	3310
99	362	5610	2870
99.9	364	1965	2500

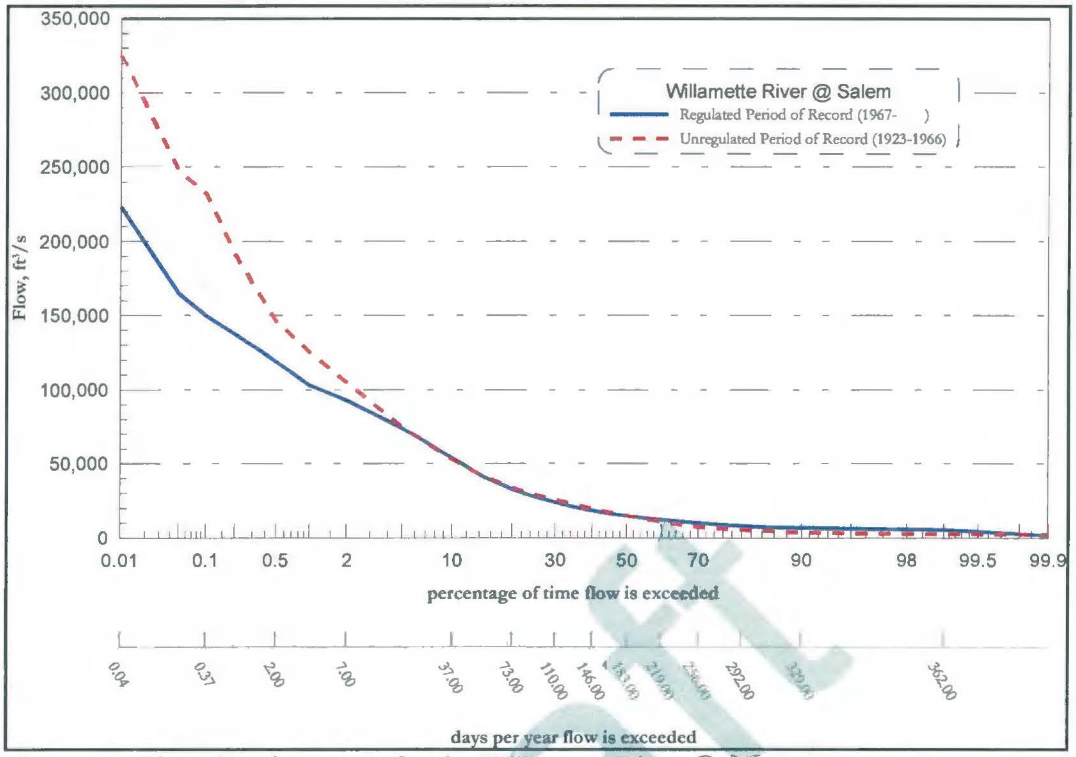


Figure 2.0: Flow-duration curve for the Willamette River @ Salem

3.3 Suspended Sediment Discharge and Unit Sediment Yield

The sediment rating curves and flow duration curves are used to calculate both water- and sediment yields at Portland for the regulated and partially regulated flow periods. The calculations are shown below on Tables 2.0 and 3.0

Table 2.0: Willamette River @ Portland (River Mile 12.8)

Willamette River @ Portland (1993-1999)

Percent Time Exceeded *1*	Percent Increment *2*	Water Discharge Q_w ft³/s *3*	Average Discharge over Time, ft³/s *4*	Sediment Discharge Q_s tons/day *5*	Daily Average Qw ft³/s *6*	Daily Suspended Qs tons/day *7*
0.01		281774				
0.05	0.04	207619	244696	149113	98	60
0.1	0.05	188719	198169	88420	99	44
0.2	0.1	173273	180996	70632	181	71
0.5	0.3	149940	161606	53341	485	160
1	0.5	129780	139860	37284	699	186
2	1	116973	123377	27326	1234	273
5	3	93240	105107	18370	3153	551
10	5	67788	80514	9490	4026	474
15	5	51030	59409	4468	2970	223

Willamette River @ Portland (1993-1999)						
Percent Time Exceeded	Percent Increment	Water Discharge Q_w ft³/s	Average Discharge over Time, ft³/s	Sediment Discharge Q_s tons/day	Daily Average Qw ft³/s	Daily Suspended Qs tons/day
1	*2*	*3*	*4*	*5*	*6*	*7*
20	5	41303	46166	2392	2308	120
25	5	34776	38039	1480	1902	74
30	5	30076	32426	997	1621	50
35	5	26208	28142	603	1407	30
40	5	23184	24696	527	1235	26
45	5	20664	21924	466	1096	23
50	5	18774	19719	418	986	21
55	5	17010	17892	378	895	19
60	5	15372	16191	341	810	17
65	5	13986	14679	308	734	15
70	5	12726	13356	279	668	14
75	5	11353	12039	251	602	13
80	5	10209	10781	224	539	11
85	5	9236	9722	201	486	10
90	5	8569	8903	184	445	9
95	5	7900	8235	169	412	8
99	4	7069	7484	154	299	6
99.9	0.9	2476	4772	96	43	1
					29,433	**2511**

Table 3.0: Willamette River @ Newberg (River Mile 48.4)

Willamette River @ Newberg (1959-1960)						
Percent Time Exceeded	Percent Increment	Water Discharge Q_w ft³/s	Average Discharge over Time, ft³/s	Sediment Discharge Q_s tons/day	Daily Average Qw ft³/s	Daily Suspended Qs tons/day
1	*2*	*3*	*4*	*5*	*6*	*7*
0.01		354,532				
0.05	0.04	269,344	311938	210873	125	84
0.1	0.05	252,903	261124	151721	131	76
0.2	0.1	208,327	230615	120543	231	121
0.5	0.3	159,254	183791	79186	551	238
1	0.5	136,250	147752	52862	739	264
2	1	114,450	125350	38988	1254	390
5	3	81,532	97991	24714	2940	741
10	5	57,552	69542	13097	3477	655
15	5	44,690	51121	7408	2556	370
20	5	37,169	40930	4908	2046	245
25	5	31,964	34567	3590	1728	179
30	5	27,904	29934	2750	1497	138
35	5	24,634	26269	2160	1313	108
40	5	21,473	23054	1786	1153	89
45	5	18,966	20220	1546	1011	77
50	5	16,459	17713	1336	886	67
55	5	14,061	15260	1133	763	57
60	5	11,772	12917	943	646	47
65	5	9,740	10756	770	538	39

Percent Time Exceeded 1	Percent Increment 2	Water Discharge Q_w ft³/s 3	Average Discharge over Time, ft³/s 4	Sediment Discharge Q_s tons/day 5	Daily Average Qw ft³/s 6	Daily Suspended Qs tons/day 7
70	5	8,110	8925	627	446	31
75	5	6,932	7521	519	376	26
80	5	6,126	6529	444	326	22
85	5	5,143	5634	377	282	19
90	5	4,240	4691	308	235	15
95	5	3,608	3924	253	196	13
99	4	3,128	3368	214	135	9
99.9	0.9	2,725	2927	183	26	2
					25,606	4122

Willamette River @ Newberg (1959-1960)

The annual water yield at Portland is calculated by multiplying the sum of column six by 365 days and converting the result to acre-feet by multiplying by 1.98. The discharge at Newberg (Table 3) is converted to a volume by the same method and adjusted to a yield at Portland by adding 26 percent additional volume to the Newberg value - as the average flow at Newberg is 74 percent of the discharge at Portland.

The annual sediment discharge in tons is calculated by multiplying the sediment sum (Tables 2.0 and 3.0) by 365 days. Because some portion of the suspended load cannot be measured, 15 percent is added to the annual values. As the sediment discharge at Newberg is 78 percent of the suspended sediment discharge at Portland, an additional 22 percent is added to the calculated quantity for Newberg (PNRBC, 1969). The adjusted annual total suspended sediment discharges are shown in column 6 of Table 4.0.

To calculate unit sediment yield the quantities in column seven are divided by the total area of the basins contributing suspended sediment to the Willamette River at Portland. As of 1967, 27 percent of the area of the Willamette River Basin was upstream of dams, thus the sediment basin area at Portland is 11,100 mi² times 0.73, or 8,100 mi². At the time of the Newberg analysis, 18 percent or 9100 mi² of the basin area upstream of Portland were regulated by dams. The results are presented below in Table 4.0.

Table 4.0: Long-term sedimentation trends in Lower Willamette River

Measurement Location (1)	Data Collection period (2)	Annual Sediment Discharge (3)	Adjusted for contributing area (4)	adjusted by sampler error, tons (56)	Adjusted Annual Total Suspended Sediment discharge, tons (6)	Sediment contributing Drainage Area, mi² (7)	Annual water Yield, ac.ft (8)	Unit Sediment Yield tons/.mi² (9)
Discharge								
Newberg	1959-1960		18,505,187				23,316,536	

Portland	1993-1999						21,271,255	
Sediment								
Portland	1949,1955				2,300,000(1)			210
Portland	1974-1981	919,196		1,057,076	1,057,076	8,100		130
Portland	1993-1999	916,515		1,053,992	1,053,992	8,100		130
Newberg	1959-1960	1,504,481	1,835,467	2,110,787	2,110,787	9,300		230

(1) Suspended load plus estimated bed load (for large,deep rivers bed load is 5-25% of total load) (Simon& Tentsrk, 1976)

3.3 Bank Stabilization (Pre- and Post Flow Regulation)

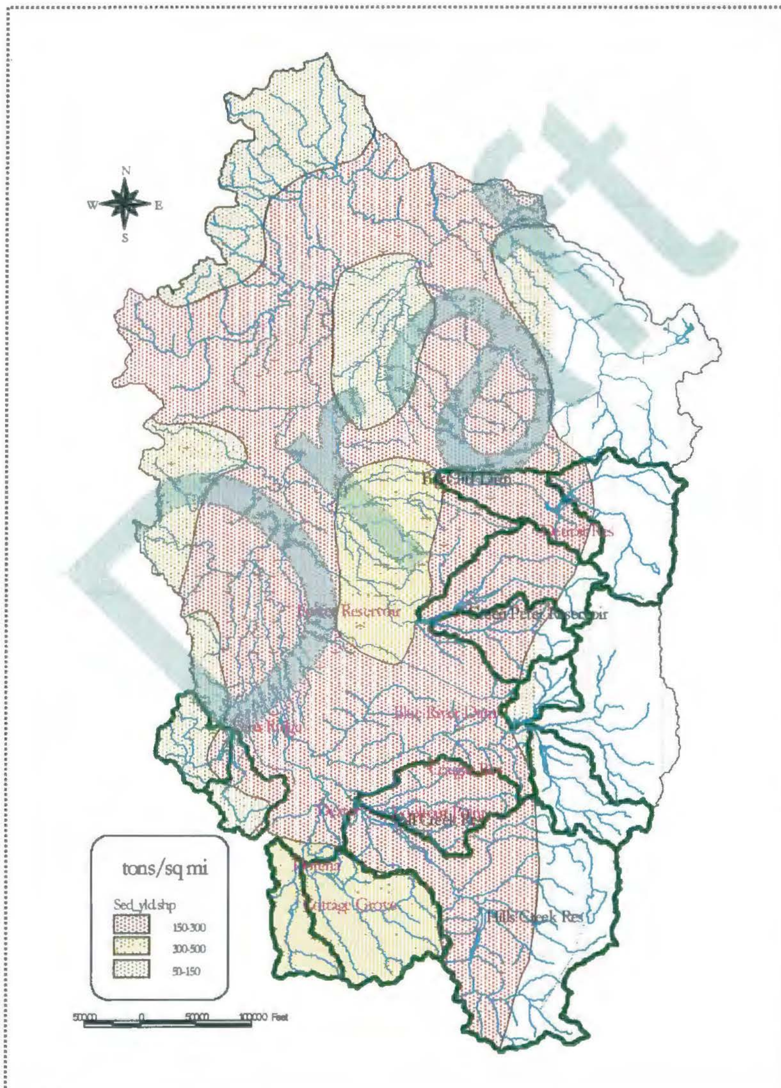
A summary of authorized bank protection projects of the Willamette River and tributaries is presented in Table 5.0. Nearly all the bank protection projects are riprap revetments, or some other kind of hard surface. None of the bank protection projects summarized in Table 5.0 were constructed to reduce sedimentation resulting from bank erosion; rather they were stabilized to prevent both lateral and longitudinal movement of the channel. Total lengths of the revetments and the percentage of the total bank length stabilized (below dams) are shown for both the pre- and post-flow regulation periods. Bank protection projects are also summarized by total length for three large tributaries of the Willamette River.

Table 5.0: Bank protection for the Willamette Rivers (and three tributary basins)

	Stream Plan Form			regulated period, >1967			unregulated period, <1966		
	channel length, feet	bank length, feet	miles	linear feet	miles	% of total bank length protected	linear feet	miles	% of total bank protected
Willamette River, including side channels and flow splits	1,194,052	2,388,104	452	249,972	47	10.5	214,544	41	9.0
All major tributaries downstream of dams	22,581,290	45,162,581	8554	260,325	49	0.6	218,183	41	0.5
			9006		**97**	**1.1**		**82**	**0.9**
All major tributaries upstream of dams	5,059,570	10,119,140	1917						
e.g. Major Basins (total lengths)									
Middle Fork Willamette	980,378	1,960,756	371	14,942	3	0.8	14,942	3	0.8
Coast Fork Willamette	978,679	1,957,359	371	22,484	4	1.1	22,484	4	1.1
McKenzie	1,399,665	2,799,330	530	56,324	11	2.0	54,645	10	2.0

4.0 Sediment Sources

Upstream of Projects: Since flow regulation began the mean annual suspended sediment discharge for the Willamette River at Portland has decreased from about 2 million tons to approximately one million tons - a 50 percent reduction in suspended sediment discharge. Although 27 percent of the total drainage area of the Willamette River basin is upstream of dams, the reduction in the sediment contributing drainage area resulting from dam construction is less[1]. A sediment yield map for the Willamette River Basin was developed by the Willamette Basin Task Force is presented on Figure 3.0 (PNRBC, 1969). A weighted total suspended sediment discharge at Portland is calculated from the map and the results are presented in Table 6. 0.



[1] The drainage area upstream of projects (at the time of sediment discharge measurements) was used for the calculation of unit sediment yields presented in Table 4.0. The size of the sediment contributing drainage is further refined for the calculations presented in Section 4.0.

Figure 3.0: The intersection of project basins and zones of equal unit sediment yield.

Project basin areas intersected with sediment yield areas and trap efficiency of reservoirs is summarized in Table 6.0. Dividing the total weighted sediment drainage amount by the weighted contribution from upstream of the projects yields a reduction in the sediment contributing drainage area of 3 percent (24 percent of total basin area).

Land cover/use is also considered in the analysis. The intersection of land cover and the project watersheds is shown of Figure 4.0. More than 83 percent of the basin area upstream of the dams is classified as forested, but little of the upper watershed area is set aside for agricultural use (less than 2 percent). The total length of tributary channels upstream of dams is shown on Table 5.0 - 17 percent of total channel length is upstream of the projects.

Table 6.0:

Sediment yield zones		Area, mi² (2)	median sediment yield, tons/mi² (3)	(2) x (3), Tons
50-150		4087	100	408,700
150-300		6040	225	1,359,000
300-500		1045	400	418,000
	Σ	**11,172**		**2,185,700**

River Basin		Area, mi² (2)	median sediment yield, tons/mi² (3)	Trap Efficiency of Reservoir %	(2) x (3), Tons
Coast Fork Willamette		104	400	89.8	37,355
Row		265	400	90.1	95,534
Long Tom		163	100	93.2	15,198
		89	225	93.2	18,671
Middle Fork Willamette		588	225	89.3	118,200
		403	100	89.3	36,005
WF McKenzie		207	100	93.8	19,421
Blue River		87	100	93.2	8,111
Fall Creek		184	225	94.4	39,095
North Santiam		348	100	90.2	31,382
		90	225	90.2	18,261
Middle Santiam		63	100	94.4	5,945
		214	225	94.4	45,433
South Santiam		140	225	85.5	26,942
		37	100	85.5	3,165
	Σ	**2982**			**518,717**

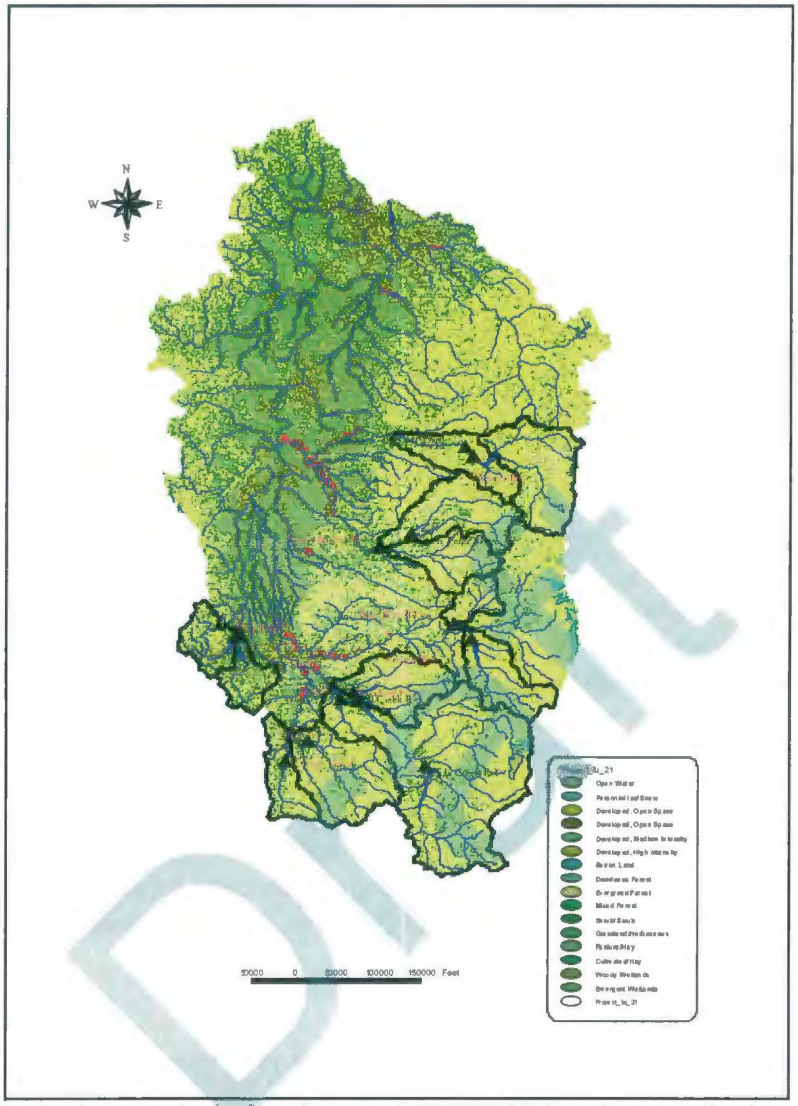


Figure 4.0: The intersection of land cover (USGS, 2001) and project basins

Downstream of Projects: The miles of channel (and bank line) downstream of dams are shown on Table 5.0. Changes to agricultural lands, notably development and changes in agricultural practices can be quantified, however the impact on sediment yield and delivery ratios cannot be reliably determined without data. However, assume a four percent reduction in unit sediment yields from all agricultural lands caused by urbanization. The Oregon Forest Practices Act of 1971 (revised in 1983) reduced sediment yield to streams from forested lands primarily through mandated design requirements for culvert sizing. One of the primary purposes of the legislation was to reduce the number of undersized culverts in forest access roads. The resulting impact to stream has not been quantified, but assume a 10 percent reduction in the amount of sediment carried to streams.

Thus, the AGU sediment discharge ratios developed from data collected in the 1950s (54% from channel erosion, 24% from forested land, 22% from agricultural land) can be updated as follows:

Forested land – 42% of all forested land in the Willamette River Basin is upstream of dams, and 83 percent of that area is forested so (0.42 x 0.83 x 0.24) x 100 equals an 8 percent reduction in annual sediment discharge from area upstream of the dam. For land downstream of the (0.58 x 0.10) x 100 equals 6 percent. Total change: - 14 percent.

Eroding channels – By channel length, 17 percent of tributary reaches are upstream of dams. However, the AGU found that 65 percent of the sediment contribution from eroding channel originated from valley reaches in the basin. Thus, (0.17 x 0.35) x 100 equals say a 6 percent reduction. The percentage of bank protected by projects (downstream of dams) changed little from the unregulated flow to regulated flow periods – thus downstream reductions from eroding channels are minimal. Total change: -6 percent.

Agricultural Land - Little agricultural land is found in the upper tributary drainages of the Willamette River Basin, and change in sediment yield is difficult to identify based on land use changes only– so assume the sediment amounts from farmland upstream of the dams is unchanged. Downstream of the projects assume a four percent loss in sediment amounts carried to streams through changes in land cover/use. Total change: -4 percent.

As the updated percentage total is 90, the values are normalized to yield the following post-regulation percentages of total sediment discharge at Portland: 1) 65 percent from eroding channels; 2) 13 percent from forested land; and 3) 22 percent from agricultural land. Using the annual suspended sediment totals shown on Table 5.0, and the original and updated delivery ratios from the three general sediment sources, the following annual amounts were calculated for pre- and post-flow regulation periods for the Willamette River @ Portland (Table 6.0)[2].

Table 6.0: Pre- and post-flow regulation sediment quantities at Portland

	Annual Amount, tons x 10^3		
Sediment Source	Pre-flow Regulation	Post-flow Regulation	Percent Change
Eroding channels	1,100	650	-41
Agricultural lands	430	220	-49
Forested lands	470	130	-72
	Σ 2000	**1000**	

[2] Climate change, notably long-term changes in rainfall amounts and intensity have not been considered in the analysis

5.0 Analysis of Sedimentation Trends

Both the sediment load and flow conditions establish the natural regime of a channel prior to construction of dam. As a dam traps all coarse-grained particles (bed material load) and much of the fine-grained material (wash load), and changes the downstream natural flow characteristics; which of the conditions prevails if either, and what is the potential degree and extent of downstream impacts with respect to channel form.

As predicted by Lane's relation (Equation 1), the release of clear water causes channel degradation downstream of a dam and a channel will deepen and widen until a geological control halts the downstream progression of the erosion. For Willamette River tributaries, bedrock (basalt) occurs in the channel a few miles downstream of the dam – one exception is the Long Tom River. In addition, the effects of reservoirs trapping sediment are most evident in streams that normally moved large sediment loads, which is not the case for any of the tributary basins of the Willamette River (PNRBC, 1969 and ASCE, 1975).

However, the effects of an imposed flow duration curve can cause changes in channel form from the dam to the stream mouth. The Corps has observed both in the Willamette Valley and elsewhere, that the bank-full capacity downstream of dam can become less than it was before the dam was built. The loss in conveyance has been explained as follows: the flow duration curve is modified by reservoir operations, such that the dominant discharge[3] is smaller with the project than without it and the magnitude and number of flood flows is reduced by reservoir operations. In either case, the overall erosive potential of flowing water in the channel is reduced. The other effect linked to a reduction in channel capacity is that continuous releases from reservoirs through the summer (see Figure 2.0) causes increased growth of vegetation at lower elevations along the channel resulting in higher bank roughness, increase bank stability at lower elevations, and increased deposition of sediment (COE, 1989).

Based on the long-term, basin-wide analysis of suspended sediment discharge, the percentage of the total suspended sediment discharge in the lower Willamette River from eroding channels has been reduced by nearly half in the last 50-55 years.[4] Because dams have reduced the contribution to sediment discharge from eroding channel in the upper tributaries minimally, and because the percentage of bank line protected by revetments has increased slightly from the 1940s to the late 1960s, flow regulation might explain the 41 percent reduction in sediment discharge from bank erosion. As illustrated in Figure 2.0, the flow duration curve has shifted down for flows exceeding 100,000 ft^3/s (at Salem gage, UGGS No. 14191000). Figure 5.0 also illustrates the impact of regulation on natural flow conditions in the Willamette River, which is a histogram of discharges exceeding 100,000 ft^3/s.

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[3] The range of flow magnitudes that determines channel cross section shape (width and depth) (Wolman and Leopold, 1957)

[4] Point of caution the methods of analysis used herein do not account for major sediment discharge events, such as the December 1964 flood. During the 1964 flood, the UGGS measured a total suspended sediment discharge of 6.5 million tons at Portland over a ten day period – nearly three times the annual total at the time.

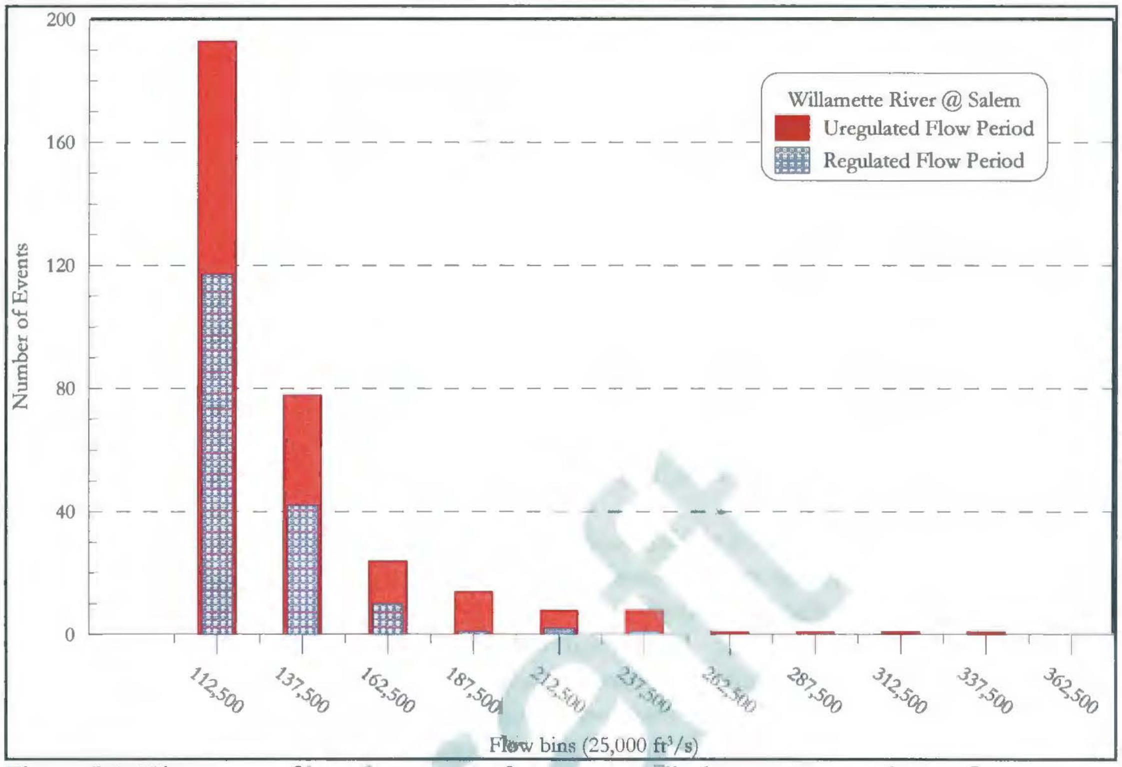

Figure 5.0: Histogram of low-frequency of occurrence discharges (pre- and post-flow regulation)

Prior to flow regulation, the number of discharges exceeding 100,000 ft^3/s was 336, after regulation - the count was 179. Before regulation in the basin, 21 flows exceeded 200,000 ft^3/s, after 1967-there were three floods exceeding that value. All the discharges shown in Figure 5.0 occurred between November and March.

In 1967, the Willamette Basin Task Force developed a general relation between water and sediment discharge – expressed as a percentage of annual total flow and total sediment discharge for any cross-section in the Willamette River (PNRBC, 1969). The relation is illustrated graphically in Figure 6.0. Nearly 83 percent of the total annual suspended sediment discharge in the Willamette River occurs between November and March. Thus, flows that transported the highest percentage of sediments have been reduced in number and in magnitude.

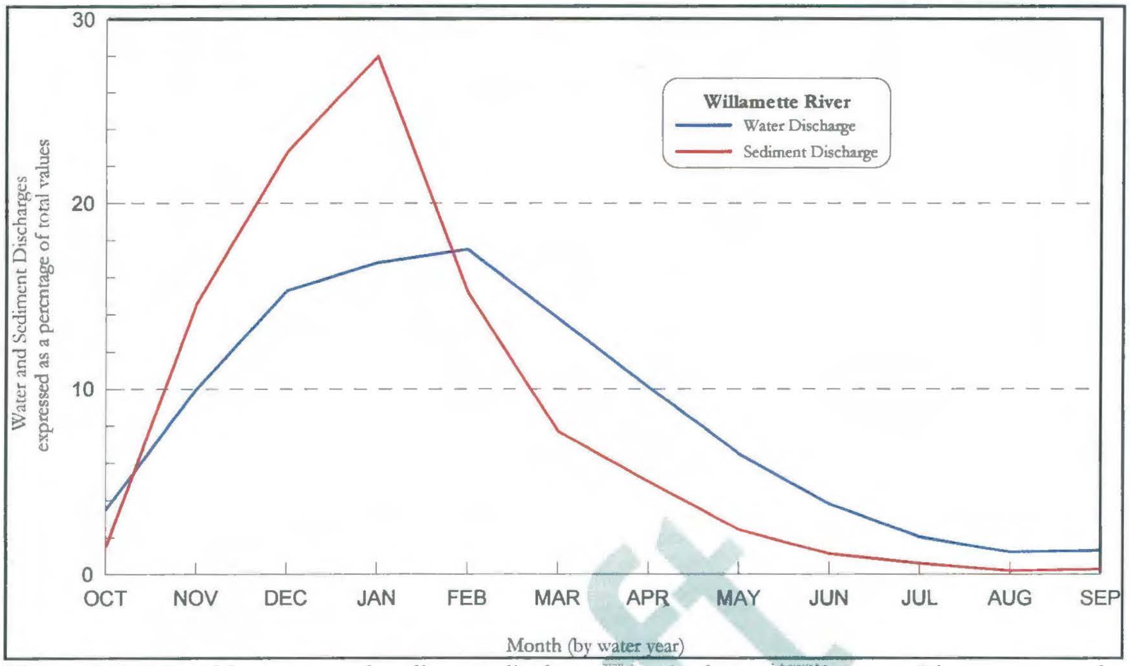

Figure 6.0: Monthly water and sediment discharges in the lower Willamette River expressed as a percent of annual water and sediment yield

6.0 Conclusions

A stream's response to changes in both water discharge and sediment discharge is complex; however, the 50 percent reduction in the annual suspended sediment discharge for the Willamette River at Portland cannot be explained solely by dams trapping suspended sediment behind them.

Clear water releases from Willamette River Basin dams have caused scour and degradation downstream. However, the extent of channel degradation is limited by geologic controls – usually a few miles downstream of the projects; and tributaries of the Willamette River were naturally under-loaded, or the sediment supplied to the stream rarely exceeded its transport capacity. For under-loaded streams, channel degradation resulting from the trapping of suspended sediments in a reservoir is limited downstream, both laterally and longitudinally. Regardless, a 24 percent reduction in suspended sediment discharge at Portland is attributable to dam construction on tributary basins.

In contrast, the impacts of changed flow conditions extend downstream to the confluence of the tributaries and beyond to the mouth of the Willamette River. Two causes of bank failure are directly related to flow magnitude and the hydraulic parameters that are functions of flow (significantly: topwidth, depth, hydraulic radius, and energy grade line slope). The two failure mechanisms are direct scour of banks and loss of bank support (undercutting). A reduction in the dominant discharge and a reduction in the number and magnitude of flood flows result in both long- and short-term (flood flows) decreases in bank and bed shear forces and a reduction in total bank surface area subjected to hydraulic forces.

Lane's slope-discharge relation for sand/gravel bed rivers is shown on Figure 7.0. The curves on the figure represent a channel's tendency to meander or braid. The region between the two extremes is a transitional range where streams are classified as intermediate in character.

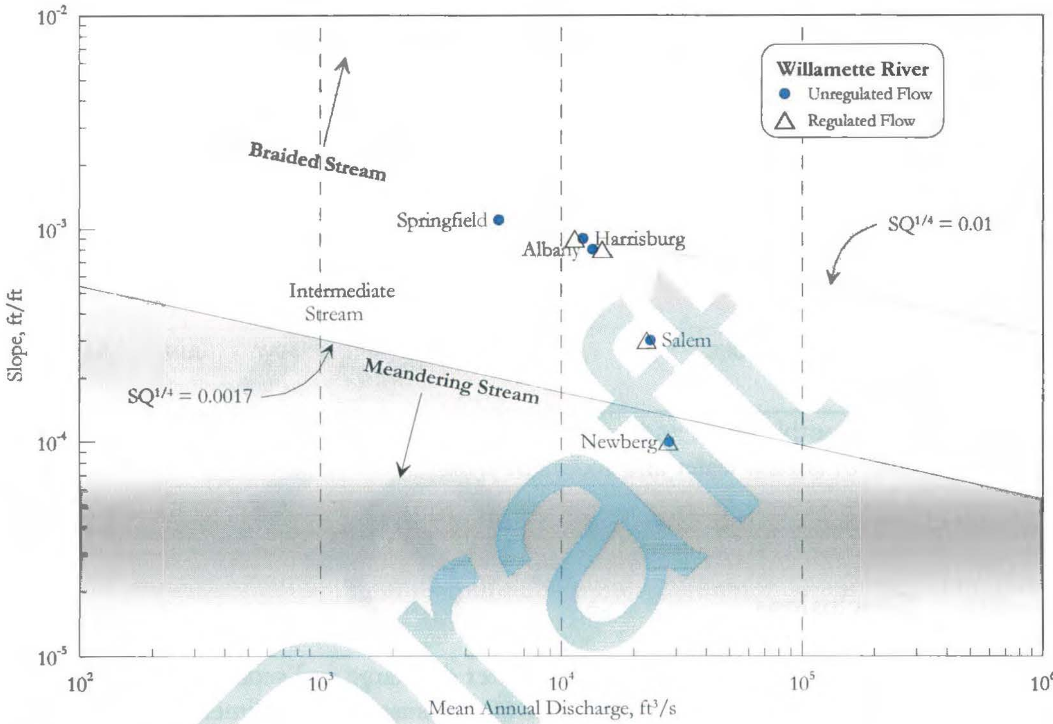

Figure 7.0: Slope-discharge relation for sand/gravel bed streams

Selected reaches of the Willamette River from Eugene/Springfield to Newberg are plotted on Figure 7.0. The Newberg reach plots in the meander zone, and the remaining reaches plot in the intermediate zone. However, with the exception of Salem, the other reaches plot in the upper part of the transitional zone where a relatively small increase in either slope or discharge in the channel upstream of Albany might initiate a tendency toward braiding. Whereas, from Salem to Willamette Falls the river exhibited a more stable meander pattern – from Newberg to the falls, the sinuosity is very low. A braided stream is unstable, changes its plan form rapidly, and carries large quantities of sediment from eroding banks and the carving of multiple channels during high flows. Thus, the significance of the plotting positions in Figure 7.0 is that the source, or former source, of a high percentage of suspended sediment from eroding channels was likely the approximately 55-60 river mile (RM) reach of the Willamette from Eugene to upstream of Albany.

Leopold and Wolman and Lane identified the primary causes of a braided channel pattern forming: 1) overloading - the stream is supplied with more sediment than it can carry (the sediment discharge exceeds the transport capacity); 2) steep slopes and high flows; or both 1) and 2) acting in concert; and 3) easily eroded banks (USGS, 1957) and (USACE, 1957).

Prior to dam building, the SCS (now the NRCS) and the Corps concluded that sediment discharge in the Willamette River and its tributaries was low. The purpose of the SCS studies was to quantify soil loss and to prevent land lost to channel migration in support of agricultural; whereas, the Corps study was conducted to develop rates of deposition in reservoirs for establishing the design life of proposed dams. Additionally, the SCS, Corps and the Forest Service concluded that the soils of the Willamette Valley are not easily erodible (erosion factors for Willamette Valley soils are available on the NRSC SSURGO database). Thus, former braiding of the upper Willamette River was predominantly of the steep slope/high discharge kind. Based on a qualitative analysis performed by the Corps in the late 1940s, investigators concluded that the bed-material load in the upper Willamette River was large compared to the suspended load (USACE, 1954). Because a primary source of bed-material size particles is eroding banks, some of the braided character of the stream may be attributed to bank erosion - despite the absence of easily eroded soils in the valley. Based on geology, topography, soils, and rainfall patterns, overloading is the least likely cause of braiding in the stream.

Currently, the upper Willamette River exhibits a more stable meandering pattern, which results in lower amounts of sediment delivered to the stream through bank erosion. While flow regulation may be a principal cause of the changed channel pattern of the upper Willamette River, it is not the sole cause. However, a discussion of other causes of change in the upper basin, such as bank stabilization, training structures, channel filling, and flow diversions are not included herein.

7.0 Recommendations

As noted in Section1.0, quantitatively predicting stream response to changed conditions is complex and sufficient data is often not available. Thus, a qualitative assessment of the Willamette River is as follows: The stream throughout long reaches has achieved a state of approximate equilibrium with concomitant reductions in effective flow and suspended sediment discharge. For engineering purposes, long reaches of the Willamette River are stable (stable conditions are also referred to as a poised of graded condition). However, because the annual total suspended sediment discharge below Willamette Falls has decreased 50 percent in the last 40-50 years, attempts to further limit sediment delivered to the stream through bank stabilization projects, regardless of the methods employed to limit erosion, is not recommended.

Regardless of the method(s) used to stabilize channels, an engineer must consider hydraulic, flood frequencies, discharge peaks and durations, interaction of tributaries, and the wash load and bed material load characteristics. Given theses requirements, channel stabilization projects are usually implemented to control local sedimentation problems (e.g. local scour), and not to correct the impacts from basin-wide changes in conditions. Regardless, many miles of channel of the Willamette River and its tributaries are on private property, and are therefore inaccessible to agencies, or organization wishing to implement bank stabilization projects.

8.0 References

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